ECONOMIC GEOLOGY

WITH WHICH IS INCORPORATED

THE AMERICAN GEOLOGIST

VOL. X JULY–AUGUST, 1915 No. 5

THE ORISKANY IRON ORES OF VIRGINIA.

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SYNOPSIS.

PAGE.

I. Introduction 399
II. The Oriskany Measures 400
Distribution 400
Description 401
History 407
III. The Oriskany Iron Ores 409
Description 409
Position 412
Genesis 413
IV. Commercial Considerations 419
V. Summary 420

I. INTRODUCTION.

Although Virginia ranks sixth among the iron-producing states, her output amounts to only about 1.5 per cent. of the total iron-ore output of the union. Roughly 65 per cent. of the Virginian output is mined from the Oriskany deposits; these deposits may be said then to contribute approximately 1 per cent. of the output of the United States.

It is clear therefore that the commercial importance of the Oriskany ores is largely a matter of local concern. As well defined types of a certain class of iron-ore deposit, however, it is believed that they possess more widespread interest.

A very considerable literature already exists dealing with the Oriskany ores. E. C. Eckel published a list of references, antedating his paper of 1905.[1] Of more recent date are the chapter on iron by R. J. Holden in the "Mineral Resources of Virginia";[2] a paper by E. C. Harder on the "Iron Ores of the Appalachian Region";[3] and the recent annual reports of the Virginia State Geological Survey.[4] Reference should also be made to the U. S. Geological Survey Folios Nos. 14, 26, 28, 32, 44, and 61, all of which include areas of Oriskany rocks.

The following discussion will necessarily review much of the ground already covered by these earlier publications, and general acknowledgment is hereby made to them.

II. The Oriskany Measures.

Distribution.

The Oriskany belt of Virginia, by which I mean that belt of country traversing Virginia wherein are found the Oriskany measures with their associated deposits of brown iron ore, extends from the extreme northern county of Frederick southwest as far as Tazewell County, a total distance of roughly 250 miles. Its greatest width is about twenty-five miles. Southwest of Tazewell County the Oriskany exposures become generally poor and soon afterwards disappear.

On Fig. 53, which is an outline map of Virginia, are shown the principal Oriskany iron-mining centers, past and present, thereby indicating the general position of the belt.

This is seen to lie practically along the northwest frontier of the state, occupying, in Virginian terminology, the southeast flanks of the Alleghany Ridges and the northwest uplands of the Great Valley Region. In a broader sense, it occupies a northwesterly position in the Central or Valley Division of the Appalachian Province, which division varies in width from 40 to 125

[1] U. S. Geological Survey, Bulletin No. 285, p. 183.
[2] T. L. Watson, The Virginia Jamestown Exposition Commission, 1907.
[3] U. S. G. S. Bulletin No. 380, p. 245.
[4] Bulletins Nos. I. *A* and VI.

miles and extends from southern New York to Georgia, being bounded on the southeast by the Appalachian Mountains and on the northwest by the Cumberland Plateau and the Alleghany Mountains.

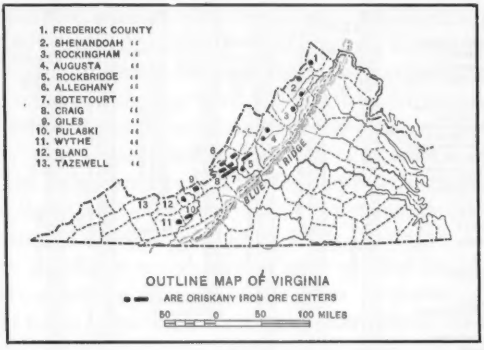


FIG. 53.

In fact the Oriskany horizon is traceable northeastward from Frederick County, Virginia, across West Virginia, Maryland. and Pennsylvania well up into New York. The vicinity of Cumberland, Md., may be regarded as the approximate center of the total Oriskany belt; here it probably finds its best development, thinning out both northeast and southwest from that locality.

Nowhere except in Virginia, however, have the associated brown iron-ore deposits been found to attain sufficient importance to form the basis of a very considerable iron-smelting industry, and it is due to the Oriskany ores of Virginia that the name Oriskany has assumed a certain degree of economic significance and dignity.

Description.

It will be understood that the belt of territory just described is by no means occupied exclusively by rocks of the Oriskany horizon; but it is within this belt that the Oriskany strata outcrop in frequently recurring and generally northeast-southwest leads. Everywhere associated with these strata are the underlying Clin-

ton and Helderberg, and the overlying Romney horizons, and familiarity with all four horizons is essential to an understanding of the structural and other phenomena presented.

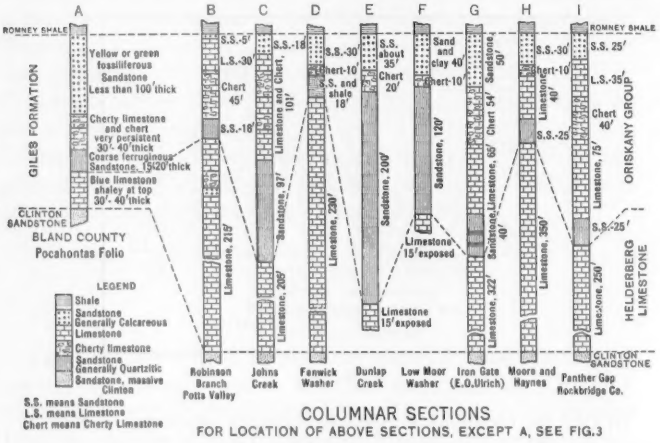


FIG. 54.

The columnar section is best exposed at the well known Iron Gate arch. This section, as measured by E. O. Ulrich in 1905, has been published by E. C. Eckel,[5] and is here repeated graphically, with some slight modification, under column *G* in Fig. 54. In the same figure is presented the section for Bland County shown in the U. S. Geological Survey Pocahontas (No. 26) Folio, and seven more or less complete sections measured by the writer at a number of other points, all within the area covered by Fig. 55, and indicated on the latter by corresponding letters.

Reference to Fig. 55 will make clear that the area included in Fig. 55, namely Alleghany and adjacent parts of Rockbridge, Botetourt, and Craig counties, is predominant in the Oriskany iron-ore industry. The writer's study has been largely confined to this district and remarks will therefore chiefly bear upon it. It

[5] *Loc. cit.*, p. 185.

may be added that this region represents the heart of the Oriskany belt, contains the most numerous and important deposits, and may be taken as truly representing the type in its best development.

Reviewing the columnar sections in Fig. 54, we note that the lowest member represented is the Clinton, which is capped by a bed of heavy quartzitic sandstone lying upon a considerable thickness of alternating sandstones and shales. Next above this comes the Helderberg, including from 200 to 350 ft. of limestone, generally thin bedded and muddy, more rarely coarsely crystalline or massive, with occasionally a few feet of quartzitic sandstone. Above the Helderberg we find the Oriskany group, which will be further described below; and finally an immense thickness of black slate and shale, assigned to the Romney horizon.

There is a difference of opinion as to whether the Helderberg measures should be classed as Silurian or Devonian, since their relations to the preceding and succeeding formations are such as to render no clearly definable separation possible. In the following table, which is intended to show the corresponding nomenclature used by various writers, they are classed as Silurian, and will hereafter be thus considered.

TABLE I.

Period.	(*a*)	(*b*)	(*c*)	(*d*)
Devonian.	Romney shale.....	VIII.	Romney shale	Romney shale
	Oriskany formation..	VII.	Monterey sandstone	Giles formation
Silurian..	Helderberg limestone.	VI.	Lewistown limestone	
	Clinton formation...	V.	Rockwood formation	Rockwood formation

(*a*) Names used in this paper; (*b*) numbers used by W. B. Rogers and others; (*c*) names used in U. S. G. S. Monterey (No. 61) and Staunton (No. 14) Folios and by Eckel, Holden, Harder and Watson; (*d*) names used in U. S. G. S. Pocahontas (No. 26) Folio.

We now turn more particularly to the Oriskany formation. It is of interest to define what belongs to this formation in order to determine the true position of the iron-ore horizon.

We note that Ulrich (see Fig. 54, column *G*) includes in the Oriskany the following members:

(1) Calcareous sandstone.
(2) Siliceous limestone with many beds of chert.
(3) Bluish-gray limestone with sandy beds in upper part.
(4) Quartzitic sandstone with two shaly beds.

Eckel, on the same page on which he presents Ulrich's section,[6] refers to "Oriskany sandstone and siliceous limestone" with a thickness of 50 to 250 feet.

Holden, however, ascribes to the Oriskany only from 0 to 15 feet of calcareous sandstone; throwing the underlying "10 to 60 feet pure thick-bedded soft fossiliferous limestone" and "20 to 60 feet cherty limestone" into the Helderberg.[7]

Harder gives credit to Ulrich's section by reproducing it[8] but on the next page closely follows Holden in his description of the Oriskany and Helderberg measures, thus:

	Feet.
Monterey (Oriskany) sandstone	0–20
Lewistown (Helderberg) limestone:	
Pure heavy-bedded limestone	10–60
Cherty limestone	20–60
Limestone and sandstone	200–

In this he would appear to be inconsistent, since without comment he robs the Oriskany in his own section of everything assigned to it by Ulrich except the top calcareous sandstone.

Watson[9] has followed Holden and Harder. The sections given in the U. S. G. S. Folios of neighboring quadrangles are generally not in sufficient detail to be of service in this discussion, except in so far as they ascribe only limestone to the Lewistown (Helderberg) formation.

Review of the sections presented by the writer in Fig. 54 shows that Ulrich's lower Oriskany sandstone is a most persistent horizon and in fact attains at some points notable thickness. Where 100 and more feet thick, with only thin beds of cherty limestone above, as for instance in columns *E* and *F*, Fig. 54, it

[6] *Loc. cit.*, p. 185.
[7] *Loc. cit.*, p. 408.
[8] *Loc. cit.*, p. 246.
[9] Va. State Geol. Survey Bulletin No. 1, *A*, p. 31.

has seemed inappropriate to separate this horizon from the Oriskany "sandstone" group and throw it with the Lewistown (Helderberg) "limestone." The question can not be settled on the evidence of fossils, since there are no marked differences in this direction. It must be rather a matter of opinion, and in the writer's judgment propriety lies on the side of grouping this sandstone with the Oriskany, as Ulrich has done, rather than to follow the second and surely inconsistent classification of Harder. It should be noted that by doing this we throw the iron-ore horizon unreservedly into the Oriskany group, since the ores are practically never found below the cherty horizon occurring in the limestone, which overlies the sandstone just now discussed. More will be said of this later.

Lyman in a paper on the "Geology of the Low Moor Iron-Ores"[10] compares a columnar section measured in the vicinity of Low Moor, Alleghany County, Va., with two Pennsylvania sections. His Low Moor section corresponds approximately with section, column *F*, Fig. 54, and he identifies the lower Oriskany sandstone with the Oriskany sandstone horizon of Pennsylvania. This identification further confirms the opinion expressed above.

The following strata are assigned to the Oriskany and Helderberg formations respectively:

	Feet.
Oriskany: (1) Calcareous sandstone	0- 50
(Iron-bearing horizon between (1) and (2))	
(2) Limestone, massive and frequently abundantly fossiliferous, including a persistent cherty horizon	10–100
(3) Massive sandstone, with occasional shale	15–200
Helderberg: Limestone, generally thin bedded, with occasional massive limestone beds and more rarely thin beds of sandstone	200–350

As regards structure, the Oriskany belt consists of a series of numerous parallel N.E.-S.W. folds, as a rule asymmetrical with the southeasterly dips gentle and the northwesterly dips high or

[10] *Trans. A. I. M. E.*, Vol. XIV., p. 598.

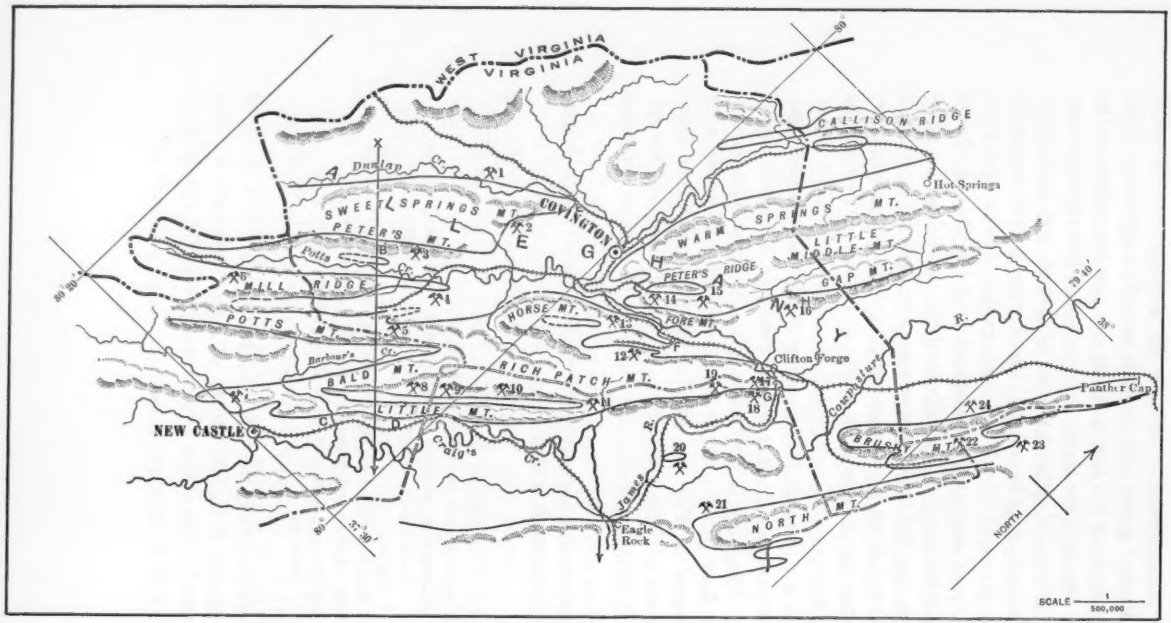


FIG. 55. Map of Allegheny and Portions of Adajacent Counties, Virginia.

x–y, Line of Geological Cross Section, Fig. 56. B, C, etc. Position of Columnar Sections, Fig. 54.

× = Mines	5. Double Ridge	10. Grace Ellen	15. Iron Mt.	20. Big Hill
1. Stack	6. Paint Bank	11. Roaring Run	16. Moore & Haynes	21. North Mt.
2. Rumsey	7. Peter's Hill	12. Low Moor	17. Alexander	22. Longdale
3. Hepley	8. Fenwick	13. Rich Patch	18. Merry Hill	23. Victoria
4. Bess	9. Oriskany	14. Dolly Ann	19. Callie, Wilton, and Circle	24. Randolph

~ Indicates approximate position of the principal Oriskany crop-lines

even overturned. The overturned folds not infrequently extend into faults, sometimes of considerable magnitude. The overthrust fault is typical of the region.

Topographic relief is roughly superimposed upon the geological structure. The more prominent anticlines, denuded down to the massive and resistant Clinton and lower sandstones, form long narrow N.E.-S.W. ridges, whose flanks are sheathed by the Helderberg and Oriskany limestones and sandstones, while the foot hills and valleys are occupied by synclinoria of Romney shale.

On Fig. 55 are traced the principal leads of Oriskany outcrops, which are seen to follow in general the flanks of the ridges. The structure is perhaps more clearly brought out in Fig. 56, a geological cross-section along the line x–y drawn on Fig. 55.

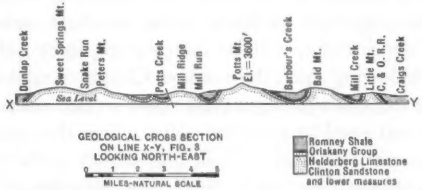


FIG. 56. Geological Cross Section along line x–y drawn on Fig. 55.

History.

It will be of interest to follow briefly the geological history of the above described formations.

In early Cambrian times a narrow strait extended from the Gulf of St. Lawrence southwestward to Alabama. This strait coincided approximately with the Central or Valley Division of the Appalachian Province, while its eastern shore probably lay about where the Appalachian Mountains now stand. Thus in Virginia we find in the Blue Ridge the ancient land margin; northwestward lay a body of water, of great extent N.E.-S.W. and with its opposite shore a hundred miles or more to the N.W. The Blue Ridge shore was somewhat mountainous, a condition which led to active erosion and the contribution of heavy masses of

2. Rumsey 7. Peter's Hill 12. Low Moor 17. Alexander 22. Longdale
3. Hepley 8. Fenwick 13. Rich Patch 18. Merry Hill 23. Victoria
4. Bess 9. Oriskany 14. Dolly Ann 19. Callie, Wilton, and Circle 24. Randolph
~ Indicates approximate position of the principal Oriskany crop-lines

coarse sandy sediments to the neighboring waters. These sediments are preserved in the so-called Potsdam (Cambrian) sandstones and quartzites, which to-day so largely make up the western slopes of the Blue Ridge.

The succeeding Cambro-Silurian period is marked by a widening of the strait westward, ultimately transforming this into a great interior sea extending westward as far as Wisconsin and beyond the Mississippi. At about the same time an uplift of considerable magnitude over northern New York and New England cut off this inland sea from the Gulf of St. Lawrence. The eastern Blue Ridge shore had by now become generally reduced to a low plain, and there was no doubt a certain amount of transgression on the part of the sea in this direction. There followed successive periods of elevation and depression, with alternating active and retarded erosion of the land surface, all of which have recorded their respective histories in the off-shore sediments. In the end of the Silurian, with its fine-grained limey (Helderberg) sediments following upon the massive Clinton sandstones, is recognized the existence of a generally base-leveled continental area to the east, margined by a coastal plain, where the coarsest of the detrital material was accumulated and stored while the shallow interior sea became the seat of calcareous deposition.

The immediately succeeding oscillations at the beginning of the Devonian period were evidently of comparatively slight extent, and gave rise to the Oriskany sandstones and locally interbedded limestones. The sandstones were, no doubt, largely derived from the marginal deposits stored along the coastal plain and now carried down to the sea through the renewed activity of transporting agents during the periods of moderate land elevation; while the limestones, with their frequently abundant fossils and their persistent chert beds, were accumulated in shallow off-shore waters during the intermediate periods of depression.

A prolonged period of elevation followed upon this series of slight oscillations and contributed, first a final capping of calcareous Oriskany sandstone, and then thick beds of shale. These latter were derived from the deep erosion products, which had accumulated upon a long low-lying land surface and which were

now washed off into the sea by the once more rejuvenated transporting agencies.

We need not go into the succeeding Devonian and Carboniferous history, as these later strata have no bearing upon our present discussion. The great vertical uplift which finally caused the retreat of the interior sea to the Mississippi embayment appears to have been independent of the horizontal mountain-building stresses which had already begun to act upon the rocks of the Eastern and Central divisions of the Appalachian Province, throwing them into the series of parallel asymmetrical folds described on an earlier page. Subsequent subaerial erosion has roughly superimposed topographical relief upon the underlying geological structure.

We may note that it is but natural to find many evidences of overlap as well as great irregularities in thickness in sediments which have been thus accumulated in shallow off-shore waters along an oscillating shore-line.

III. The Oriskany Iron Ores.

Description.

The ores are commercially known as "brown iron-ores," and include all forms of hydrated oxides, intimately associated with varying amounts of sand, chert and clay.

The ore-bodies occur in the form of tabular-shaped lenses of highly irregular and uncertain dimensions, always conforming in their general attitude with the enclosing measures. In size they range from small flat pockets, containing only a few tons, to far larger bodies assuming more truly the physical characteristics of veins. In the latter case they may be as much as a couple of thousand feet long, and at least several hundred feet on the dip, with a thickness varying from 5 to 30 feet.

The longer dimension of the ore-body appears to coincide, as a rule, with its strike-line, though in some cases this dimension would seem to have a pitch down the dip. The deposit is not always longest on its crop; in one well-known case at least it is several hundred feet longer at a couple of hundred feet beneath the

surface than it is on the crop. Holden[11] says: "the ore may extend 700 feet on the slope from the outcrop," and from Harder we learn that "at a considerable depth, perhaps about 300 to 400 feet, the ore deposit begins to get thinner and limestone appears on both hanging and foot walls until finally, at a reported depth of about 600 feet, the ore gives place to solid limestone."[12] It has been the experience of the writer that no definite law governs the depth to which the ore-bodies may extend, except that they have nowhere, to his knowledge, been followed below ground-water level, while they frequently have proved to be far shallower. The depth dimension is as uncertain as any other. The deposits are found running out into sand more commonly than into limestone. At the Fenwick Mine, on the other hand, the bottom car-level is in high grade ore, of full width and with no sign of change, at a depth of 550 feet on the slope from the outcrop and 112 feet vertically below the bed of the adjacent creek.

The hanging wall of the ore-body may be shale or clay, or else a highly ferruginous sandstone, locally known as cap-rock. At times sand only slightly stained with iron overlies the ore, and still more rarely the hanging wall is limestone. The foot-wall is sand, chert (commonly called flint), clay, or sometimes limestone. The contact between ore and shale, clay, limestone, or flint is always well defined, but where the ore lies against cap-rock or sand, there is usually a transition zone of lean sandy ore between the two.

Cases are known where two or more veins overlie one another at intervals of a few feet with barren material between; as a rule, such reduplication can be explained, however, by overthrust faulting. Not infrequently bands of flint are found within the ore, but rarely are beds and pockets of ore found underneath the true flint horizon, and then of very limited extent only.

In the following table are brought together the records of 420 typical drill-holes, all giving complete sections from shale to flint, which were put down at various points within the territory covered by Fig. 55. The purpose of the table is to exemplify the

[11] *Loc. cit.*, p. 410.
[12] *Loc. cit.*, p. 248.

varying cases of succession of materials and show the proportion of each case to the total. The results of these 420 holes may be considered as approximately representing the Oriskany type as a whole.

TABLE II.

Succession of Material.	No. of Holes.	Proportion %.
Shale—ore—flint	155	37.0
Shale—ore—sand—flint	163	38.8
Shale—ore—sand—ore—flint	21	5.0
Shale—ore—sand—ore—sand—flint	2	0.5
Shale—sand—ore—sand—ore—sand—flint	2	0.5
Shale—sand—ore—sand—ore—flint	3	0.7
Shale—sand—ore—sand—flint	12	2.8
Shale—sand—ore—flint	62	14.7
	420	100.0

In the above table, lean ore, that is mixed ore and sand, has been classed with ore. Possibly 5 per cent. of the holes bottomed in limestone instead of in flint, but since the drillers made no distinction, it has been impossible to differentiate here. A number of drill-holes in different localities passed from shale directly into flint, while a great many more passed from shale through sand into flint. These barren holes are, of course, not included in the above tabulation.

There are occasional deposits, but none of importance, entirely enclosed in shale. These are, however, not true Oriskany ores; they will be referred to again later.

Passing now from the walls to the ore, we find this (as noted on an earlier page) intimately mixed with sand and clay, so much so that a complete separation of the pure iron-oxide is a commercial impossibility. The high-grade nearly pure ore is sometimes porous and shelly, at other times exceedingly compact and hard; while cavity-filling forms such as stalactitic or botryoidal masses are not rare. When mixed with sand, this latter may generally be seen as innumerable minute rounded grains, imbedded in a matrix of iron-oxide; at other times it appears as soft residual kernels enclosed in concretionary shells of siliceous ore, or else as more or less angular blocks of hard sand, coated, stained, and frequently veined with iron-ore. Horses of sandy ore are a com-

mon occurrence in a vein of otherwise high grade material, and veinlets of clean ore are often seen running through sandy material. Pockets and stringers of clay and bands of flint are not uncommon, while occasionally rounded blocks of limestone stand out into the vein, or are enclosed within it.

From one-half to two-thirds of the vein material mined and sent to the washer is recovered as washed ore, carrying from 40 to 45 per cent. metallic iron. The balance, being clay, loose sand, flint, and lean sandy ore, is removed.

Position.

Eckel, Holden, Harder and Watson, while granting some slight latitude in the matter, are unanimous in placing the Oriskany ore-horizon essentially in the upper part of the Lewistown (Helderberg) limestone. This follows naturally upon their grouping of the various sandstone and limestone members, whereby they give to the Oriskany only the very uncertain top calcareous sandstone.

As a matter of fact, the ore is very often wholly enclosed in this top sandstone, as shown by the large percentage of cases in Table II. where the footwall of the ore-body is sand; and in all such cases the ore is Oriskany by position even by the Harder grouping of the strata.

The writer has given reasons for believing, however, that the Oriskany should be grouped as Ulrich has it, namely to include the lower and far more persistent sandstone member. This arrangement throws every known Oriskany ore-body unreservedly into the Oriskany horizon, and the name thereby becomes a name in fact, and not merely one for convenience as suggested by Eckel.[13]

Lyman's correlation of the lower Oriskany sandstone at Low Moor with the Oriskany sandstone of Pennsylvania is quoted in support of these views in this matter of grouping. The writer is unable to agree with Lyman in his identification of the Oriskany ores with the ore-bed found in the Marcellus shale of Pennsylvania. Arguing from a single section he presents a plausible case; but acquaintance with many sections convinces one that the Oriskany

[13] *Loc. cit.*, p. 184.

ores are never underlaid by shale, and that where underlaid by clay (as in Lyman's Low Moor section) this clay is not residual out of shale, but out of limestone. The deposits do not in fact occur any higher in the geological scale than beneath the base of the Devonian shale; they can not therefore correspond "with the Marcellus ore-bed, so valuable in the Juniata Valley and southwesterly towards the Potomac," but must rather be correlated with "the uncertain poor deposits of brown hematite found at places in the same region along the outcrop of the Oriskany."[14]

Exception may be taken to the statement that the Oriskany ores are never enclosed in shale. Occasional small pockets of brown ore are in fact found in the shale, but nowhere do these attain any slight degree of economic importance except perhaps towards the north in Shenandoah County, where for example, the Liberty mines are described by Holden as occurring in Devonian shale "a few hundred feet stratigraphically above the Oriskany horizon."[15] Passing still further northward, we find nothing of note in West Virginia, but in Maryland Singewald records some small and unimportant deposits which he groups under two horizons, naming them the Marcellus-Oriskany, and the Helderberg-Oriskany respectively, and correlating the latter with the Oriskany ores of Virginia.[16] It would appear that the former should be correlated on the one hand with the Marcellus ore-bed of the Juniata Valley in Pennsylvania, and on the other hand with the northern Virginian brown-ore deposits occurring within shale such as that at the Liberty Mines. These shale deposits therefore are not Oriskany, but should rather be classed as equivalents of the Marcellus.

Genesis.

It must be understood that while maintaining that the ores under discussion are properly called Oriskany, the writer so calls them primarily on the ground of their position. Their age is a matter for discussion.

[14] *Loc. cit.*, p. 599.
[15] *Loc. cit.*, p. 431.
[16] ECONOMIC GEOLOGY, Vol. IV., p. 531.

Older writers have held that the Oriskany ores were syngenetic in origin, being derived through weathering and hydration out of original beds of iron-carbonate deposited with the enclosing sandstones and limestones. This theory is reflected in Lyman's suggested correlation of the Oriskany ores with the Marcellus ore-bed of Pennsylvania. According to Eckel[17] iron carbonate has indeed been found at several points in the deeper portions of the Longdale Mines. The writer has nowhere as yet encountered any.

Other syngenetic hypotheses have been advanced by later writers; as for instance by Darton, who, in speaking of the Oriskany deposits in the neighborhood of Buffalo Gap, Augusta County, refers to unconformities by erosion between the Monterey (Oriskany) sandstone and its underlying neighbor and suggests that "the iron-ores accumulated as bog-deposits on the more or less completely bared limestone surface."[18]

Again Campbell, whose section for the Giles formation in Bland County is given under column *A*, Fig. 54, says:

> "Ore occurs in the Giles formation probably in small quantities only. This is the famous Oriskany ore of Virginia, but in the Pocahontas field it appears to be more intimately associated with the limestone stratum than with the sandstone. From the presence of limestone pebbles in the Oriskany sandstone, as well as from the mode of occurrence of the ore itself, it seems probable that the ore is due to subaerial disintegration of the limestone which then formed a land surface and the segregation of the ferruginous matter in the residual clay. This probably occurred contemporaneously with the deposition of the sandstone; so the ore may be classed as Oriskany in age, though formed directly from Helderberg limestone."[19]

In 1908 H. M. Chance advanced the theory that certain brown iron-ores were derived largely in place from syngenetic deposits of iron-sulphides, and suggested the applicability of this theory of origin to the Oriskany ores.[20]

In the meanwhile the replacement theory supplemented by some proportion of cavity-filling had come into vogue. Johnson advo-

[17] *Loc. cit.*, p. 186.
[18] U. S. G. S. Folio No. 14, Staunton.
[19] U. S. G. S. Folio No. 26, Pocahontas.
[20] *Trans. A. I. M. E.*, Vol. XXXIX., p. 536.

cated this theory in his paper on "The Origin of the Oriskany Limonites,"[21] and was followed by Eckel, Holden, Harder and Watson. Catlett defends this theory in a discussion of Chance's paper just referred to.[22] All agree in ascribing the source of the iron to the Devonian shale. Johnson says that a sample of this shale of "a good brownish-black color" ran 2.5 per cent. metallic iron. Eckel in a paper on "Brown Iron-Ores as Cavity-Fillings"[23] quotes an analysis of clay taken from a cave in the Low Moor (Alleghany County) limestone quarry, which contained 6.18 per cent. ferric-oxide, saying:

"This analysis corresponds quite closely with a number of analyses of the unaltered black shale."

Harder expounds the replacement theory as follows:

"The iron composing the Oriskany ores is derived from the overlying Devonian shales, which are black and very rich in iron minerals. Upon weathering, the shales are decomposed and the iron is carried downward in solution by meteoric waters. The solutions have penetrated the underlying Monterey (Oriskany) sandstone, in which iron oxide has been deposited along fractures and has abundantly replaced the cement between the sand grains. Where the sandstone is sufficiently thin and fractured the solutions have penetrated the underlying Lewistown (Helderberg) limestone and have replaced the calcium carbonate by ferric oxide and thus formed iron-ore deposits."[24]

It is no doubt admitted, from the evidence of stalactitic and similar forms not infrequently encountered, that cavity-filling has supplemented to some degree metasomatic replacement.

Catlett says:

"The waters, which are heavily charged with iron sulphate from the decomposition of the slates, find a ready channel in the sandstone, where they mingle with the waters derived from the limestone, and in turn aid in the decomposition of the latter. The result would be the formation of iron carbonate, and then of iron oxide and calcium sulphate, with the disintegration of the limestone. The calcium sulphate being readily soluble, would usually be entirely removed. The most common plane of

[21] *Engineering and Mining Journal*, Vol. 76, p. 231.
[22] *Trans. A. I. M. E.*, Vol. XXXIX., p. 919.
[23] *Engineering and Mining Journal*, Vol. 96, p. 2.
[24] *Loc. cit.*, p. 249.

deposition would be the contact between the limestone and the sandstone, leaving a part of the sandstone as a ferruginous hanging-wall."[25]

Any one conversant with the facts which I have attempted to set forth in the preceding pages, must necessarily recognize that the present evidence is preponderantly in favor of the replacement theory. There can be no question but that this process is chiefly responsible for the development of the ore-bodies as we see them to-day; but in the opinion of the writer some question may perhaps properly be raised as to their original condition and as to the source of the iron which, as shown above, has been attributed solely to the overlying slates.

The writer has noted with much interest the following statement by J. F. Kemp when describing the Oriskany ores in his chapter in "The Iron Ore Resources of the World";[26]

"... there is a stratum of limestone called the Helderberg lying beneath a sandstone known as the Oriskany. The sandstone carries sufficient iron to have yielded the metal to the descending meteoric waters. The waters have encountered the limestone and have replaced it with limonite. ..."

Overlooking the fact that he places the ore-horizon in the Helderberg limestone, wherein he follows the authorities whose opinion in this direction has already been fully discussed in the foregoing pages, attention is called to the source to which he attributes the iron, namely the Oriskany sandstone.

Holden has attacked this statement in a review of the Iron Ore Resources of the World, saying:

"In the description of the iron-ores of the United States it is stated in regard to the Oriskany ore that 'the sandstone carries sufficient iron to have yielded the metal,' implying that the sandstone was the source of the ore. This is incorrect. As a matter of fact, the Oriskany sandstone does not carry enough iron to have yielded the metal. As an hypothesis this is new to the reviewer and is open to serious question inasmuch as the sandstone is thinner than the ore-bodies."[27]

[25] *Loc. cit.*, p. 919.
[26] Vol. II., p. 764, Stockholm, Sweden, 1910.
[27] Economic Geology, Vol. V., p. 691.

Two phenomena observed by the writer lead to the suggestion that Kemp may, in part at least, be right.

The first of these is the frequent absence of ore-bodies at such points where they might in all reason be expected to exist. There are, of course, conditions which would militate against their formation under the replacement theory with the slate as the source of iron, such as a high or overturned attitude of the strata, or a heavy and massive top Oriskany sandstone; and where such conditions exist one would not ordinarily look for a deposit of ore. Johnson and others have recognized this and have formulated rules for the guidance of prospectors. Catlett, after enumerating a set of conditions which must combine to produce an ore-body, says:

> "The result is that while the Oriskany ores are found over a large territory at a particular geological horizon, they vary greatly in their development, and through only a small percentage of the extent of that horizon are they found in workable condition."[28]

This last is even more true than conditions would seem to warrant, and not only of ore-bodies but even of any traces of ore whatsoever; assuming that the iron owes its source to a pretty generally iron-bearing overlying slate. The writer has in fact often been puzzled by the complete absence of ores where all conditions appeared to be dominantly favorable to their accumulation.

On the other hand instances may be cited where ores have been found under unfavorable conditions. It is admitted that these cases are far rarer than where ores are absent under favorable conditions, and may be set down as the inevitable exceptions. Still they have some force as corroborative evidence.

The second phenomenon to which the writer desires to call attention has to do with faulting.

Holden[29] says:

> "The ore . . . has not been deformed or fractured since it was deposited."

[28] *Loc. cit.*, p. 920.
[29] *Loc. cit.*, p. 410.

Numbers of cases have been encountered in surface cuts, underground, and in drill-holes, where the ore-body occurs on both sides of an overthrust fault. This possible evidence regarding the age of the ore-body is by no means conclusive. Frequently it has been apparent that the overthrust limb of the ore-body has reached nearly, if not quite, to the surface, and for this or for some other reason, has been as accessible to attack by replacing solutions as the underthrust limb. On rarer occasions the probable course of the solutions which, according to the replacement theory, have been responsible for the ore-deposit has been more difficult to explain, and it has seemed possible that the deposit in such cases antedated the fault, being thus syngenetic.

One more point may be touched upon in this connection. The advocates of the replacement theory, with the slate as the source of the iron, make much of the part that the limestone has played in the formation of the ore-bodies. As a matter of fact, the ore-bodies are frequently wholly enclosed in sandstone. Two explanations are, of course, here possible; that the ore has replaced a highly calcareous sand, or that it was original in the sand.

While admitting that no one of these several observations has great force in itself their joint corroborative evidence leads the writer to advance the suggestion that original iron-ores, syngenetic with the Oriskany sandstone, may have been largely responsible for the iron and in some cases may even have provided nuclei about which ore-bodies were built up. The overlying shales may have furnished a supplementary source of iron, and replacement processes are certainly responsible for their development as we see them to-day.

The complete absence of bodies of sulphide ore at depth in the Oriskany mines renders Chance's theory of genesis out of original pyritic bodies untenable. Furthermore the only evidence in favor of the "original iron-carbonate" hypothesis, namely the very occasional presence of such material, may be explained equally well by deposition in bogs, or by replacement; and other facts are adverse to this hypothesis.

It appears to the writer that the bog-iron theory may not so readily be discarded. The conditions at the time of the deposition

of the Oriskany measures were favorable to the formation of bog-ores, here and there in lagoons along the shallow, gently oscillating shore-line. Nor are the physical characteristics of the ores necessarily discordant with this theory. The in part illogical distribution, or perhaps better illogical absence, of the ores is readily accounted for in this way; as is also the evidence that some part of the ore-bodies may possibly have existed before faulting took place.

My conception therefore involves the following suggestions: that bog-ores were formed during Oriskany times, generally lean, sandy, and shallow, frequently little more than ferruginous impregnations of sandstone; and that these deposits were subsequently concentrated and enriched, or else were wholly transported to new environments, through the agency of meteoric solutions. In short the original bog-ores may have supplied nuclei about which ore-bodies were built up, or else they may have contributed their iron to the enrichment of lower portions of the same or of separate bog-deposits, or to the building up of entirely fresh ore-bodies. The iron thus derived was no doubt supplemented at times, and possibly to a considerable extent, by iron derived from the decaying shales.

It will be seen that this conception accepts the replacement theory quite as set forth above and for which there is undeniable evidence, except as regards the source of the iron. It is suggested that this latter may have been largely derived from original deposits in the Oriskany sandstone itself, though certain contributions have without doubt also been made out of the shale. In other words, the writer desires to superimpose the replacement theory upon an original syngenetic bog-iron-ore theory.

IV. Commercial Considerations.

A very few words under this head must serve the purposes of this paper.

The Oriskany ores were formerly mined largely in open-cuts following the croppings of the veins, but to-day there are only two such operations. Surface showings at various localities as yet unexplored or relatively inaccessible give promise however

of further bodies of ore which may in the future be cheaply won by open-cut hand or steam-shovel methods.

In the meanwhile, present workings are principally underground. The top-slicing and caving system employed has been described by Hungerford[30] and again by Holden.[31]

The crude ore from open-cut or underground work is transported to a washer where it is more or less effectively cleaned of foreign matter, such as clay, sand, flint, etc., by means of log-washers, screens, picking-belts, jigs, classifiers, and separators. The washed ore, which generally amounts to from one half to two thirds by weight of the crude ore, is collected in railroad cars and sent to the local blast furnace for conversion into pig-iron.

The washed ores carry from 40 to 45 per cent. metallic iron, about 0.4 per cent. phosphorus, varying amounts of manganese, and small but persistent quantities of zinc.

The larger companies make it their practice to continuously search for new ore-bodies or for extensions of those under operation, the search being carried on chiefly by means of steam-driven churn drills. The ores cut in these drill-holes are carefully sampled and records are prepared with maps, showing their location, elevation, depth, and history, with quantity and quality of ore cut. Promising territory is frequently fairly riddled with such holes, the lack of persistence of the ore-body in any direction being well recognized. When an ore-body of commercial value has thus been discovered and outlined, the records make it possible to trace its contours and so determine the most advantageous method for its exploitation.

V. Summary.

The Oriskany belt of Virginia follows the Northwest frontier of the state, from Frederick to Tazewell counties, a total distance of about 250 miles. Its width is upwards of 25 miles. Within this belt, the Oriskany strata are found in frequently recurring N.E.-S.W. leads, lying in a series of parallel asymmetrical folds in association with overlying Romney shale and underlying Helderberg limestone.

[30] *Trans. A. I. M. E.*, Vol. 7, p. 103.
[31] *Loc. cit.*, p. 482.

The Oriskany horizon has been commonly described as comprising a single bed of thin calcareous sandstone, while the immediately underlying cherty limestone and sandstone horizons have been assigned to the Helderberg limestone. It appears more appropriate to include in the Oriskany group everything from the lower and more persistent sandstone bed upwards, leaving from 200 to 350 feet of limey sediments to the Helderberg.

The brown iron-ore deposits, which have given economic dignity to the Virginia Oriskany measures, are found in the upper portion of the Oriskany strata as grouped above, never lower than the cherty limestone and always below the overlying Romney shale. Such deposits as are found within the shale should be regarded as the equivalents of the Marcellus of Pennsylvania.

The ore-bodies are comparatively rare and lack persistence. A number possessing distinct commercial value have been discovered and worked however in times past and present, and the field is by no means exhausted. The deposits are tabular-shaped lenses, sometimes with extensive dimensions which warrant their description as veins. They may be wholly enclosed in sand, or far more rarely in limestone; frequently they have a hanging-wall of either shale or sand and a foot of chert. The ores are sometimes high-grade limonites, either shelly and porous, showing cavity-filling forms or else compact and dense; more commonly they are mixed with sand, clay and flint.

Ores are mined both in open-cuts and underground. They are transported to washers, where the foreign matter is more or less efficiently removed, and from one half to two thirds of the crude is recovered as washed ore carrying from 40 to 45 per cent. metallic iron.

Recent theorists all ascribe the origin of these deposits to replacement processes, with the overlying shale as the source of the iron. It is suggested however that the iron has, to a great extent, originated in syngenetic bog-iron deposits in the Oriskany sandstone; and that replacement processes have later served to concentrate and enrich such original deposits, or else to transport their iron to new and perhaps more favorable environments. The shale has no doubt furnished a supplementary source of iron.

THE OIL POOLS OF SOUTHERN OKLAHOMA AND NORTHERN TEXAS.[1]

JAMES H. GARDNER.

INTRODUCTION.

The discovery of the Healdton oil pool in the southern portion of Oklahoma, during the latter part of 1913, has thrown new light on the geology and oil possibilities of that part of the state. The Healdton pool is, at the present writing, one of the largest in the mid-continent field. It is the third field to be discovered in Oklahoma south of the Arbuckle-Wichita uplift, the other and older pools being the Wheeler district in Carter County and the Madill field in Marshall County.

The Wheeler, Healdton and Madill pools lie near the Texas line and fall into the same geographic province as the Electra, Burkburnett and Petrolia areas of northern Texas. The Wheeler and Healdton pools fall also into the same geologic classification as the Texas fields, bearing oil from nearly the same group of rocks and on structure produced by the same general mountain building forces. In these fields the oil comes from the Carboniferous rocks, but the Madill field is in the Cretaceous, bearing oil from the Trinity sand at the base of that system; in this respect the Madill pool is exceptional to all the remainder of the great pools of Oklahoma which produce oil from the Pennsylvanian rocks almost entirely.

The Madill field has been described by Taff and Reed in Bulletin No. 381 of the United States Geological Survey, and since it falls into a very minor position with respect to the other pools and is not in the same geological classification, the same will not be discussed in detail in this paper. Structural folding, either

[1] Prepared for the Geological Society of America, December meeting, 1914, at Philadelphia, Pa.

through pressure or settling of the unconsolidated beds, probably the latter, has accounted for the concentration of the small amount of oil found at Madill. Gas in considerable quantity has been found in the Trinity sand of the Cretaceous south of Madill in Marshall County near Woodville; some showings of oil also are found there but the Cretaceous area in Oklahoma offers small chances for production of any note. The Cretaceous oil is exceptionally high grade, however.

The Petrolia and Electra fields have been described by Udden and Phillips in Bulletin No. 246 of the University Geological Survey of Texas. In this bulletin maps of the two districts are presented along with a general discussion of the surface and underground geology of both pools. The map of the Electra field is not contoured, though structural folding and terracing have there accounted for the concentration of oil. The Petrolia pool is shown by a structure contour map which outlines an irregular, elongated dome, some 200 feet high and having an area of about seven square miles. The axis of this structure extends in a west-northwest and east-southeast direction.

The primary object of the paper here presented is to furnish structure contour maps of the Healdton and Wheeler pools which lie across Red River in Oklahoma and to call attention to certain interesting data that bear on the district as a unit.

Of the Wheeler and Healdton fields, the Healdton field is the more interesting in that it is larger and supplies oil of much higher gravity. The Healdton pool is producing approximately 40,000 barrels per day at the present time (December, 1914), while the Wheeler field, or Oil City district, is inactive and producing not over 75 barrels of low grade, asphaltic, fuel oil. The Healdton field lies to the southwestward farther down the dip of rocks toward the main basin, the oil coming from an older geological horizon. The Wheeler oil has a gravity of about 19 Baumé, whereas the Healdton oil averages about 30 Baumé gravity. Farther still into the basin lie Petrolia and Electra, where oil is obtained of a quality which ranks at the front with the best grades of the mid-continent field.

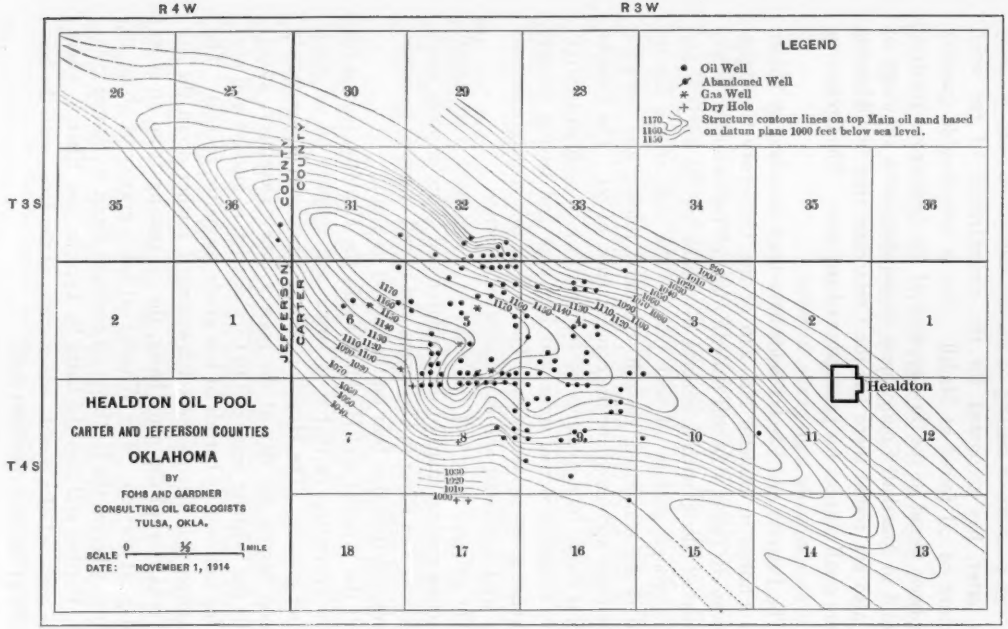


FIG. 57. The Healdton Oil Pool.

THE HEALDTON POOL.

Attention is especially directed to the accompanying contour map of the Healdton field. The structure is here shown on a contour interval of ten feet and is based on a datum plane one thousand feet below sea level for the top of the Healdton sand, levels above sea having been run to the various wells. The field lies along a distinct bulge in the Healdton anticline which runs in a general northwest-southeast direction, parallel to the Arbuckle-Wichita uplift. The anticline is continuous to the northwest, the Loco gas field lying on another bulge on the same axis.

The Healdton anticline shows a "lift" or reverse dip of about 180 feet to the northeast, as contoured on the oil sands. The surface beds show the fold very distinctly and it is understood that the United States Geological Survey will prepare a contour map showing the extent of conformity between the surface and the underground sands. This move is to be highly commended.

To the southeast of Healdton there is a gradual deepening of the measures at the rate of about one hundred feet per mile except where interrupted by additional folding. Some of this deepening does not show in the surface rocks but is due to the thickening of the "Red Beds" as if the basin were filled in from the center with a gradual encroachment on the shore. This point will be referred to further on.

The surface rocks at Healdton are the "Red Beds," which David White has shown to be Permian in age. The time interval between the beginning of deposition of the "Red Beds" and the ending of deposition in the underlying Pennsylvanian beds was very brief, though this is not in accord with some writings on the subject. However, Gordon states that the Permian is conformable in Texas. The conclusion here reached is based on detailed well logs which have recently been completed. Near the Wichita-Arbuckle uplift, the "Red Beds" as mapped by Taff and others show both erosional and angular unconformity with the underlying beds. This condition is the true one at that point, but back away from the mountains a short distance, well logs

FIG. 57. The Healdton Oil Pool.

show that the "Red Beds" everywhere rest on the same underlying beds of the Pennsylvanian with certainly very slight if any erosional unconformity; in fact the logs show a transition of Pennsylvanian deposits into those of the overlying "Red Beds." A chart is presented with this paper which gives the logs and locations of these various wells which have been completed in the summer and fall of 1914. Near the mountains where the "Red Beds" lie across the upturned edges of older rocks, coarse débris from the land areas is evident in the basal sandstone, but away from the mountains in Jefferson and Cotton counties, and continuing on across Red River into Texas, the "Red Beds" show no such condition in the well logs. The logs are remarkably consistent in showing the continuation of the Healdton sands in the underlying Pennsylvanian at the same interval down from the base of the "Red Beds" at all points. Near the base of the "Red Beds" thin lentils of blue shale and beds of gray sandstone show that typical Pennsylvanian deposits were repeated for a short time in the lower "Red Beds." It appears quite probable that deposition was continuous from the Pennsylvanian into Permian time off to the south and southwest of the area marked by the Arbuckle-Wichita uplift. The area affected by the uplift was essentially local, and not of a regional character. Since Permian time and before that of the Cretaceous there was a subsequent period of deformation that folded the "Red Beds" and at this time probably the main folding of the Pennsylvanian also took place. There is not yet evidence that at any point except near the mountains have the Pennsylvanian beds been folded, subsequently eroded and then "Red Beds" deposited angularly across them, and then again folded. The regional condition that appears to have folded the beds at Electra, Petrolia, and at intermediate points toward Healdton was post "Red Beds" in age and involved a stratigraphic section deposited in conformable sequence. Whether the structure at Healdton as shown on the surface conforms in detail to the deep sand structure remains to be seen; but certainly it is true that the surface of the "Red Beds" shows the folding distinctly on the Healdton anticline, the

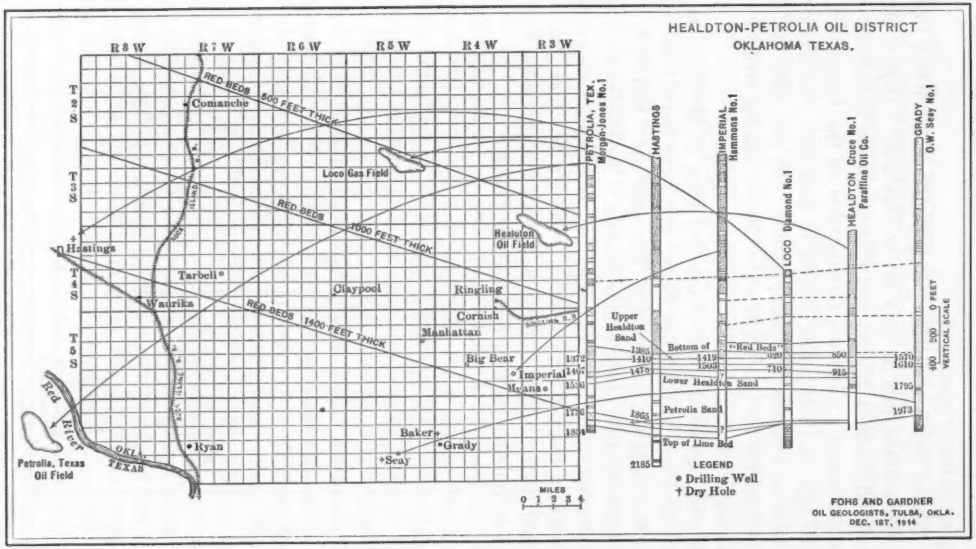
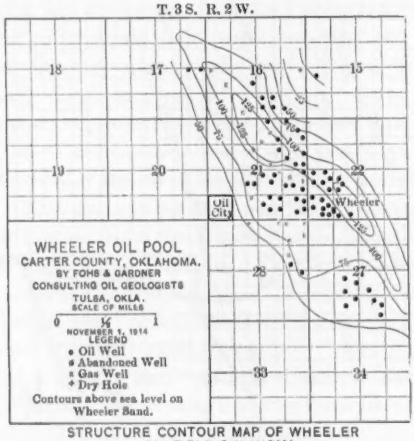


FIG. 58. The Healdton-Petrolia Oil District Oklahoma, Texas.

dome having been mapped by F. J. Fohs immediately after the discovery of the original well.

At Electra and Petrolia the "Red Beds" or "Wichita Beds" lie at the surface just as they do at Healdton. Udden places the main oil sands at Electra and Petrolia in the Pennsylvanian, but in the writer's mind the classification of the formations in the well logs of those pools is open to question. Certainly the deep sand at Petrolia is Pennsylvanian. In any case the fact remains that the surface rocks show the oil bearing structure at Electra and Petrolia.

The well logs of the area south and west of Healdton show that the thickness of the "Red Beds" is greater toward the basin than is shown in the surface dips; but since the "Red Beds" lie on the same stratum of the Pennsylvanian it becomes evident that the thickening is due to a "filling in" of the basin with a gradual encroachment toward the mountains, so that the older strata of the "Red Beds" do not outcrop at all but are concealed by the overlap of younger beds in the same formation.



STRUCTURE CONTOUR MAP OF WHEELER OIL FIELD OKLAHOMA.

FIG. 59.

THE WHEELER POOL.

The Wheeler pool has been described by F. Julius Fohs,[2] and the facts here presented are largely abbreviated from his article in order to accompany the structure contour map presented with this paper.

This pool is similar in character and parallel to the Petrolia pool in Texas, but the oil is found at a lesser depth. The structure is that of a domed anticline, such as characterizes most of the good pools in the mid-continent field. In a general way the anticline upon which the Wheeler dome is located strikes northwest-southeast, parallelling the general trend of the Arbuckle-Wichita uplift, and being directly in line with the Criner Hills uplift. It appears probable that the post-Pennsylvanian uplifts in this region were succeeded by post-Permian folds of more gentle character, following the old established lines of weakness. The pre-Permian beds were much more sharply folded; they were in fact turned almost vertically along the Criner Hills uplift, as well as where the larger Arbuckle uplift is approached. Post-Pennsylvanian erosion then truncated the rocks so that the oil and gas contained in the Pennsylvanian sands were exposed to escape at the surface, leaving only the heavier residues in the form of the asphalt deposits. Thus drilling in this vicinity to greater depth than the base of the "Red Beds," maximum in the Wheeler field about 1,025 feet, appears unwarranted, and a sheer waste of time and money. The Wheeler oil is 18 to 19 degrees Baumé gravity and occurs in the basal sandstone of the Permian "Red Beds." It is Fohs' opinion that the accumulation of the oil should be attributed to a reconcentration of the residues obtained during the process of erosion of the Pennsylvanian beds. The heavy asphalt deposits along the north side of the Criner Hills uplift in the upturned beds of the Pennsylvanian are directly in line with the Wheeler dome. However, the oil springs in the Wheeler field, together with the asphalt rock deposits of the surface represent oil accumulations in these upper beds, due to the

[2] "Petroleum and Natural Gas in Oklahoma," by L. C. Snider, published by the Harlow-Radcliffe Company, Oklahoma City, Oklahoma.

domed structure, and therefore in a manner parallelling the main oil and gas sands below. These facts are worthy of recognition in the search for new pools.

Three beds of commercial importance are found in the Wheeler field, the two upper ones being chiefly gas bearing, whereas the lower one is an oil sand with gas only at the crest of the dome. The uppermost gas sand lies at a depth of about 230 feet and the other one at about 600 feet. The surface altitudes at the tops of the wells range from 1,010 to 1,078 feet above tide. The main oil sand at the base of the "Red Beds" varies in character from fine to very coarse gravelly sand, with a thickness varying from 10 to 60 feet. The pool is confined to that area of the structure where the sand rises from 60 to 140 feet above sea level; below the 60 foot-contour, salt-water is encountered, while above the 125 foot contour gas rather than oil is present in all except one instance. The gas sands vary from 3 to 10 feet in thickness and are not structurally parallel to the oil sand, but the crests of their domes are pushed slightly to the southwest. The general trend of the anticline is northwest-southeast and the fold is necessarily elongated in that direction, having a productive length of three times its width. Water sands occur irregularly through the measures.

With this paper there is submitted a map of the Wheeler pool which shows the structure on a contour interval of twenty-five feet. It will be seen that the oil is found here along a definite anticline lying in a generally northwest-southeast direction. The lift or rise of this fold on the northeast side is 125 feet. This is the reverse side to the direction of normal dip, or, in other words, the back dip toward the Arbuckle Mountains. This anticline has two distinct bulges along the crest and pitches off at the two ends. The direction of the axis is nearly at right angles to the direction of pressure as sent out from the mountain uplifts, just as is true of the anticline at Healdton and at the Loco gas field.

GENERAL NOTES.

Practically all the oil of Oklahoma and northern Texas is found in the Pennsylvanian beds, in different sands lying from the Mississippian throughout the Pennsylvanian series to the Permian. Some production in Oklahoma at Healdton and near Lawton as well as at Wheeler is obtained from sands in the "Red Beds," as is true at Electra and Petrolia, Texas. In eastern Oklahoma some oil is found in sands lying in the topmost limes of the Mississippian. The small amount of Cretaceous oil has been alluded to above, but the percentage of all the oil found outside of the Pennsylvanian beds to the entire production is very slight.

At the present writing (December, 1914) the state of Oklahoma is producing approximately 350,000 barrels of oil per day, pushing close to California for national leadership. Of this amount approximately 100 barrels per day are being produced from the "Red Beds" at Wheeler and the Cretaceous at Madill. About one half of one per cent. is being produced from formations outside of the Pennsylvanian. Of this half of one per cent. the large amount is being produced from irregular sands in the Mississippian.

Throughout east-central Oklahoma there are over 100 distinct oil pools, the largest of which, at the present writing, is Cushing, with a daily output of over 200,000 barrels, or nearly two thirds of the entire state production. The oil pools lie, in the main, west of the Ozark uplift and north of the Arbuckle-Wichita uplift. But the Madill, Wheeler and Healdton pools lie over on the south side of the Arbuckle Mountains near the Texas border.

It is evident that the grade of petroleum increases in quality directly as the distance from the Ozark uplift increases. This is the reverse condition to the quality of coal under similar conditions. Metamorphism of coal near uplifts changes its fuel ratio in proportion to the distance from the mountains, the higher carbon coal being nearest the mountains where heat and pressure have driven off the volatile constituents consisting chiefly of water and the gaseous hydrocarbons, leaving the percentage of

carbon proportionally high. This fact was shown long ago to be true of the Appalachian Coal Field and has since proven to hold good for the large coal basins of the western United States. But metamorphism of oil reduces its quality. The volatile constituents are those that determine the value of petroleum. Whenever the higher products, such as gasoline, benzine, and naphtha, are driven off through volatilization, the oil remains of heavier gravity and correspondingly lower value on the market. The writer is of the opinion that evaporation and absorption have been the main factors in accounting for the low gravity of most oils, rather than difference in the original materials of origin. An oil of slightly asphaltic base and high gravity will through evaporation become an oil of low gravity and have a base composed essentially of the heavy mathas. This is, in fact, what happens in the lowering of the grade of oil on exposure in open tanks. The same results can be accounted for in considering the geological conditions under which oil occurs from place to place. While it is evident that an oil of paraffine base is essentially different from an oil of an asphalt base, yet it must be borne in mind that each of these two grades vary greatly in different fields and in different portions of the same field. An oil pool that occurs on structure which is faulted so as to give volatilization an opportunity to go on unequally from point to point over the structure is apt to have several grades of oil even in the same sand. This condition is shown in certain pools on the steeply dipping, faulted domes of Wyoming. Regional conditions duplicate local conditions. The fact that oil is low gravity in the highly folded beds of California and in the volcanic regions of Mexico is not at variance with the idea that heat and pressure have caused a decided volatilization of the light constituents just as happened under similar conditions to coal. The high grade of oil in the Cretaceous beds of Wyoming and in lignite-bearing Tertiaries of India show that the geologic age of the formations are not a determining factor in the quality of the oil. High grade petroleum in recent geological formations which have been subject to very slight metamorphic action, is not

exceptional. Near the Arbuckle Mountains in Oklahoma asphalt is of common occurrence both in rocks now at the surface and in those beneath the surface. At numerous points near the mountains, the Oklahoma Geological Survey has described surface sands that are impregnated with asphalt. Near the north side of the mountains oil has recently been found in the Pennsylvanian beds near Ada and Allen, but it is also a low grade oil. Then, near the mountains on the south side lies the Wheeler pool which is in much more steeply folded rocks and of correspondingly lower grade.

In Cotton and Tillman counties, north of Electra and west of Healdton, M. J. Munn has mapped for the United States Geological Survey a long, continuous meandering anticline described in Bulletin No. 547. Subsequently C. H. Weggemann and others have mapped structure recommended by the Survey for testing in southwest Jefferson County. The policy of the Geological Survey to give something of direct practical value to the oil men in advance of development is arousing considerable interest in the results of testing these structures. The work of David White in palæontological and lithological studies in this territory will eventually clear some knotty problems in the details of stratigraphic correlation and in the interpretations of the physiographic record.

Numerous reports by private geologists have been made over the area that lies between Healdton and Petrolia and divergent opinions have resulted, but most of them have manifested faith in this section of the country in testing additional anticlines which are known to lie in that region. The important point for the geologist to work out in this section on any particular anticline is to locate the high point along the axis, or bulge in the structure; water has unquestionably confined the oil and gas to the bulges. But the soft and lenticular character of the "Red Beds" there makes this part of structural mapping extremely difficult.

The many oil pools of Kansas, Oklahoma and northern Texas practically without exception show structural conditions that explain the concentration of oil and gas in those respective districts.

On the average the structure is low lying; in other words dips varying from the horizontal to 100 feet per mile characterize the degree of folding in the different pools. Locally dips of 200 feet or more per mile are found. In most all of these pools except where outcrops are totally concealed the surface rocks show the nature of the oil and gas bearing structure, the folding in every case being post-Pennsylvanian. As never before geological work in the oil business has demonstrated its value in the mid-continent field, so that gradually, but none the less surely, oil operators are coming to appreciate applied geology as a practical science.

THE ANCIENT SEDIMENTARY IRON ORES OF BRITISH INDIA.

C. M. Weld.

Iron ores are widely distributed in British India. They are found to occur: (1) Among ancient unfossiliferous sediments; (2) disseminated through granites or schists; (3) as segregations or concentrations within areas of basic igneous rocks; (4) in the coal-measures; (5) in the form of surface laterites. All these types have furnished ores in the past to the once flourishing native iron industry, but in a modern sense only the first type so far as is known today offers deposits of real economic value.

It is true that the clay iron-stones of the Raniganj (Bengal) coal fields furnished for many years the entire ore-supply of the Bengal Iron & Steel Co. at Barakar. These ores are found as bands, lenticular masses, and strings of nodules of limonite, being the weathered portions of beds of "blackband" or carbonate ore enclosed within shales of the Damuda (coal-bearing) series. They analyze 43 to 45 per cent. metallic iron, about 16 per cent. silica, and about 0.8 per cent. phosphorus. Of late years however the available supply has been approaching exhaustion, and the Bengal Company has turned its attention to more distant but richer deposits of the first type.

The future of the Indian iron and steel industry is without question bound up with the ore-deposits of this first type, and it is to them alone attention is called in the following pages.

The Ancient Sediments.

The rocks associated with this important type of deposits are amongst the oldest sediments in India. They are commonly classed as Dharwars, but sometimes as Gwaliors. All are so far as known unfossiliferous. The generally accepted correlation of these and their neighbors, above and below, with supposed Amer-

ican equivalents is shown in Table I.[1] The correspondence of the Indian iron-bearing series with the American Huronian rocks is extremely interesting.

TABLE I.

	A. C. Lawson (1913), Lake Superior Region.	T. H. Holland (1906), Peninsular India.
	Upper Cambrian (Potsdam)	Paleozoic
	Unconformity	*Unconformity*
	Algonkian: Keweenawan / *Unconformity* / Animikie	Purana: Vindhyan / *Unconformity* / Gwalior
	Eparchaean Interval	*Eparchaean Interval*
ARCHÆN	Algoman (granite-gneiss batholithic in Huronian)	Post-Dharwar eruptives
	Irruptive Contact	*Irruptive Contact*
	Huronian: Upper / *Unconformity* / Lower	Dharwar
	Unconformity	*Unconformity*
	Laurentian (granite-gneiss batholithic in Ontarian)	"Bundelkhand" type of deformed eruptives
	Irruptive Contact	*Irruptive Contact*
	Ontarian: Keewatin / Coutchiching	"Bengal" type of schists oldest gneisses

The practically universal characteristic of the Indian iron-bearing series is the presence of banded hematite- and magnetite-quartz rocks. These rocks range from pure dense quartzite on the one hand to pure massive iron ore on the other, every conceivable gradation between the two extremes being found at some point or other and often within the same area. Bluish banded quartzites, ribboned jaspers, magnetite- and hematite-quartz schists, all are common. The pure ores are found in bodies ranging from mere films to great tabular lenses, conformable in their longer dimensions with their siliceous neighbors. As a rule the ore-

[1] Sir Thomas H. Holland, "The Archæan and Purana Groups of Peninsular India," International Geological Congress, Twelfth Session, Canada, 1913, p. 376; Ottowa, 1914.

bodies do not have sharply defined walls: ore and siliceous banded ferruginous rocks grade one into the other.

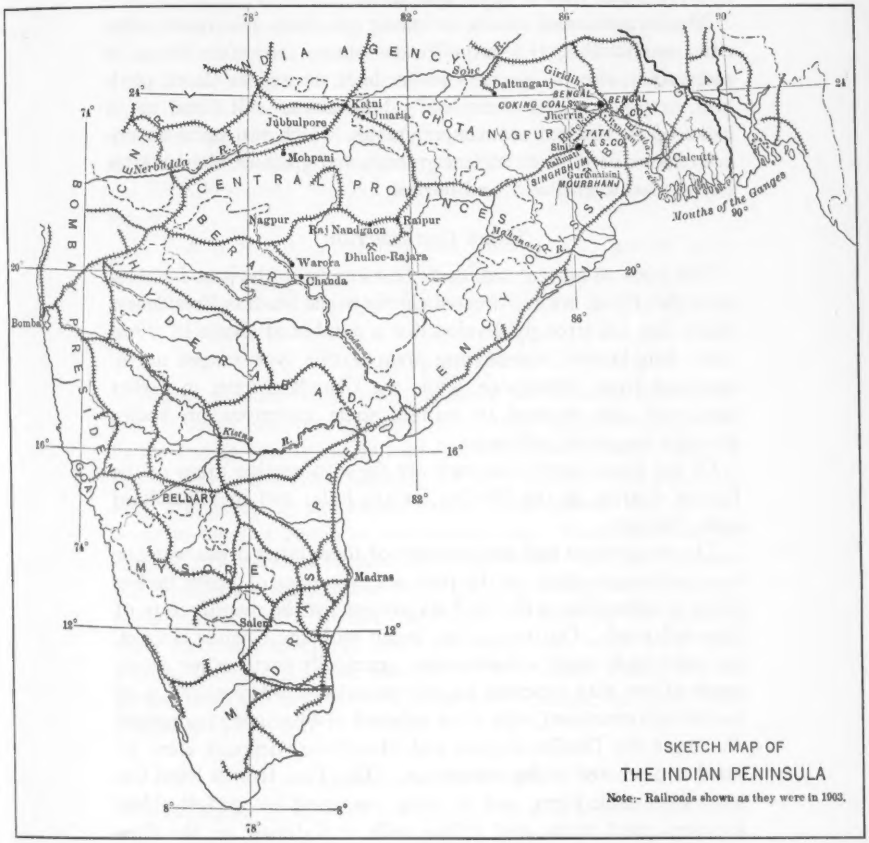


FIG. 60.

The ores are not always dense and massive; at times they are laminated and slightly porous, and not infrequently they are mica-

ceous, disintegrating to a powder when handled. In these cases, however, they are usually more directly associated with slaty and schistose rocks than with the quartzites.

Many varieties of schists, including quartzose, micaceous, chloritic, amphibolitic, and garnetiferous phases, are often found in association with the quartz-iron-ore beds, as well as slates, phyllites, trap-flows, and occasionally limestones. All these go to make up the ancient sedimentary series, which rest upon an uneven floor of still more ancient granites and gneisses, charnockites (hypersthenic gneisses) and norites.

Their Distribution.

The areas of ancient sediments best known in the past for their contents of iron ore are situated chiefly in the Madras Presidency, where they are strongly developed at a number of localities. Another long-known iron-bearing area of this type ranges northeastward from Jubbulpore, while the Chanda district in earlier days was also reputed to contain some enormous ore-bodies amongst its ancient sediments.

Of far more recent discovery are the iron-bearing areas of the Raipur district, in the Dhullee Rajara hills; and in Mourbhanj state, Bengal.

The recognition and development of these latter areas was due to a prolonged study of the iron ore resources of India undertaken in connection with the Tata project for the manufacture of iron and steel. Our researches began with the Chanda district, and later took under consideration practically every other occurrence of ore that appeared to give promise. Many points were visited and examined, only to be rejected as of minor importance. At length the Dhullee-Rajara and Mourbhanj deposits were located and secured under concession. The Tata Iron & Steel Co. soon after took form, and is today operating successfully blast furnaces, steel-works, and rolling mills at Kalimati, on the Bengal-Nagpur Railway, 155 miles west from Calcutta. Its present ore supplies are being drawn from the Gurumaishini deposit in Mourbhanj, while the Dhullee-Rajara ores are being held in reserve.

Besides the five conspicuous areas named above, namely the Madras Presidency, the Jubbulpore and Chanda districts, the Dhullee-Rajara hills, and Mourbhanj state, there are many localities of minor importance where ancient iron-bearing sediments exist. Such for instance are the Notu and Buda hills in western Singhbhum, whence the Bengal Iron & Steel Co. have proposed to draw their future ore supplies. All localities which have at any time been considered of first-rate importance however are included in the list of five, and it is these the writer proposes to describe, the first three very briefly, the remainder in somewhat greater detail.

In fact it is only these last two which are of proved great economic value today; though it is quite possible that future search in the remoter jungle districts will bring forth other deposits of equal value.

Madras Presidency.

The occurrences of Dhawar rocks in the Madras Presidency are abundant and very typical. A number have been described in the Indian Geological Survey literature, particularly those of the Bellary and Salem districts.[2] While iron ores are plentiful, they are generally intimately banded with quartz and do not occur in massive bodies of commercial size. Some projects for magnetic concentration have been discussed. At best however the deposits are far removed from the only coking coals in India, namely those of the Bengal coal-fields, and schemes for utilizing them have not prospered since the early days when they were smelted in small charcoal furnaces by Mr. Josiah Heath and his successors, the Porto Novo Steel & Iron Co. and the East India Iron Co. (1830–1867).

Jubbulpore District.

The Jubbulpore deposits are less typical than those of southern India, the iron-ore-quartz rocks being present in rather subordinate amounts and usually schistose and micaceous. Their associates are schists, slates and phyllites. The masses of pure ore are contained in the latter quite as often as in the siliceous rocks, and

[2] Geol. Survey of India, Memoirs, XXV., and XXX., Pt. 2.

are generally micaceous, yielding for the most part a powdery rather than lumpy ore. The deposits were examined in 1903 by Messrs. Edward P. Martin and Henry Louis, on behalf of Sir Ernest Cassel, but were pronounced unsatisfactory both as to quantity and physical character.[3] Earlier reports had attributed immense supplies to these deposits.

Chanda District.

The ores of the Chanda district were examined by the writer during the early months of 1903. Here again early reports were not borne out as to quantity, though quality proved to be of the best. Massive bodies of pure hard ore were found scattered over several hundred square miles of ancient land surface. The "country" was granite and gneiss, with here and there small patches of schists and quartzites and occasional limestones. These patches were concluded to be mere remnants of once probably far more extensive areas of Dharwarian sediments. The ores were always closely associated with the sediments, generally with quartzites. Their present narrow limits, at depth as well as horizontally, as proved by careful examination and some exploration, is undoubtedly due largely to extreme denudation and degradation.

The Dhullee-Rajara Deposits.

These ores were briefly noticed in a paper by P. N. Bose on "The Iron Industry of the Western Portion of the District of Raipur."[4] Mr. Bose takes note of a number of points in the territory covered by him. Under the caption "Daundi-Lohara Zemindari," he says: "The richest and most extensive ores of the district are to be found in this zemindari. . . . The hill of Dalhi, for about seven miles of its length, is full of good hæmatite, which is developed in hard red, rather thin-bedded ferruginous Chilpi sandstone." Analyses of two samples from "Dalhi" showed 72.92 per cent. and 67.41 per cent. Fe respectively.

The writer first visited the Dhullee hill in the early summer of

[3] *Agricultural Ledger*, Calcutta, 1904, No. 3.

[4] Records Geol. Survey of India, Vol. XX., 1887, Pt. 4, p. 169.

1903, and returned in September, after the rains, with four hand diamond-drills, and conducted explorations for several months.

The village of Dhullee lies forty miles nearly due south of Raj Nandgaon, a station on the Bengal-Nagpur railroad 402 miles from the Tata Iron & Steel Co.'s works at Kalimati, 557 miles from Calcutta, and 657 miles from Bombay. The forty miles are travelled over fairly good roads through open, gently undulating country of the ancient land surface type, which is typical of the great plain of the Deccan (Hyderabad). Two rivers of considerable size are forded. The occasional sharp inequalities in the surface are due to the upturned edges of more resistant formations such as the quartz-iron-ore beds, and are never more than a few hundred feet high. These ridges are rather thickly wooded, but for the rest the country is covered with a sparse scrubby jungle growth, interspersed here and there with the paddy-fields of small villages.

The ancient sedimentaries are found in a horseshoe-shaped basin about eight miles across its points, which lie toward the west. This we called the Koosumkussa basin, from a village situated at about its center. The rims of the basin are marked by quartz-iron-ore ridges, bordered on the outside by schists. On the south and east is the long tortuous ridge known as the Dhullee-Rajara hill. On the north is the Bugmar ridge, so-called from an adjacent village of that name. The interior of the basin is occupied by phyllites and trap, with a number of minor quartz-iron ore ridges, roughly parallel to one another and to the sides of the basin.

Outside the basin on the south, east, and north, are seen granites and gneisses. The northern border of granite extends northward a few miles only, when it disappears under sandstones which form the southern rim of the great Chhatisgarh basin of Vindhyan sediments. That this basin once extended further southward is seen in the occasional outliers. To the west the country is almost wholly occupied by trap.

The above geological features are represented on Fig. 61, while Fig. 62 shows a geological cross-section taken on the line *A–B* and looking west.

It will be noted that there are two horizons of quartz-iron-ore beds. The lower appears in the long Dhullee-Rajara ridge on the south and east of the basin, but thins out northward and disap-

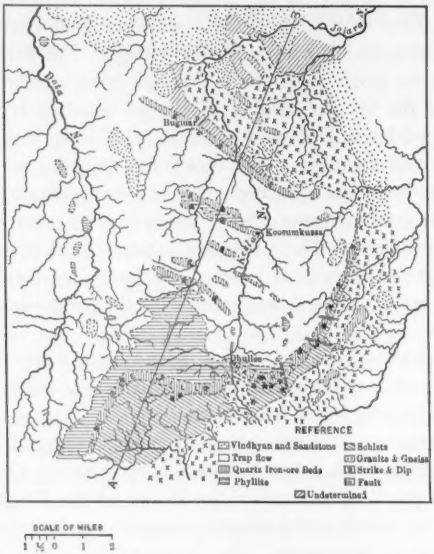


FIG. 61. Geology of the Koosumkussa Basin. Dondi Sohara Lemindari Raipur Dist. C. P. Incending the Dhullee Rajara Iron Ores.

pears. It is not certain whether this has been cut off by some younger granitic intrusion, or whether it simply feathers out, presumably along an ancient shore-line. While it is quite possible

FIG. 62. Idealized geological cross-section on sine A-B, looking north west, across the Koosumkussa Basin, Dondi Sohara Lersindari, Raipur District, C. P. India.

that there are some post-Dharwar intrusives within the area, the last appears to be the more natural interpretation of this phenomenon and has been adopted in my cross-section. The upper horizon forms the northern rim of the basin. It is seen in the Bugmar ridge, and reappears to the south in the several minor parallel ridges, presenting a shallow synclinorium.

It has been indicated above the granites and gneisses are probably for the most part older than the ancient sediments, forming the floor upon which these rest. Of the sediments, the oldest are quartzites (in one case appearing conglomeratic), and quartz and mica schists. Next above are quartz, amphibole, magnetite and garnet schists.

Next in ascending order is the lower quartz-iron-ore bed. This contains, as well as quartz and iron ore (both hematite and magnetite), subordinate amounts of pyroxene, amphibole, grünerite, and garnet. Phases range from dense white to bluish quartzite, barely dusted with microscopic inclusions of iron ores, to pure massive ores with no visible quartz. The intermediate banded varieties are very common, often presenting a striking ribbon-like wavy or crenulated structure. The massive ore-bodies range from thin bands to great tabular lenses a hundred or more feet thick, from two to three thousand feet long, and of undetermined depth; always conformable with the enclosing rocks. The walls are generally not sharply defined. The lenses feather out on their strike, only to come in again further on.

The upper quartz-iron-ore bed is in all respects similar to the lower, except that it contains only comparatively small bodies of ore, all the valuable deposits so far discovered being in the lower bed. The phyllites which intervene between the two iron ore beds consist essentially of a loose-textured, evenly-colored white to yellow to pink material, generally rather soft and almost greasy to the touch but occasionally sandy. At times the pink varieties pass over into a deeper red harder and denser material.

The trap-flow lies unconformably above the upper quartz-iron-ore bed. This is for the most part a fine-grained massive green rock whose essential constituents are quartz, feldspar, augite and hornblende. At times it is porphyritic, the phenocrysts being

rather small, stout needles of hornblende; and occasionally rounded black spots of ilmenite are conspicuous, giving the trap an amygdaloidal appearance. Specimens subjected to microscopic examination were reported as hornblende schists, but only occasionally does the trap present a schistose appearance to the eye.

Surface lateritic accumulations are quite common, chiefly resting upon the phyllite. Wherever they are upon or close to the quartz-iron-ore beds, they are frequently rich in iron due to the inclusion of ore fragments and a limonitic matrix.

A number of large lenses of pure ore occur in the lower quartz-iron-ore bed, occupying the crest of the Dhullee-Rajara ridge. Only one of these was drilled, several holes bottoming in ore at a depth of 125 feet. As a result of our work, a fair estimate of ore above drainage in this one body would be ten million tons. The Dhullee-Rajara ridge as a whole undoubtedly contains many times this amount. The average of 113 samples, from surface and drill-cores, gave the following analysis:

	Per Cent.		Per Cent.
Fe	67.45	Sulphur	0.090
SiO_2	1.68	Phosphorus	0.061
Mn	0.16		

A complete analysis of a mixture of samples proved the absence of baryta, zinc, copper, nickel and cobalt, lead, titanium, and chromium, and showed a trace only of arsenic.

Mourbhanj State.

Although the ores of this state are now being drawn upon by the Tata Iron & Steel Co., they were actually never as thoroughly studied or explored as those of the Dhullee-Rajara deposits, because the abundant surface showings were sufficiently convincing without more careful exploration at depth. Therefore my information regarding their geology is far less complete.

Our attention was first called to the Mourbhanj ores by Mr. P. N. Bose, then geologist for the state. A little later Mr. Bose

published a paper entitled "Notes on the Geology and Mineral Resources of Mayurbhanj."[5] Some part of the general information given in the following is taken from Mr. Bose's paper.

Mourbhanj state is one of the Orissa feudatory states of Bengal. A large proportion of its 4,243 square miles of surface is mountainous, several peaks rising to about 3,000 feet above sea-level. This "hill-country" is generally heavily forested and is underlaid by granites, gneisses, charnockites and other ancient intrusives, with here and there patches of ancient sediments. The latter include quartzites, phyllites, and a variety of schists, as well as banded quartz-iron-ore rocks; and may be referred to the Dharwar series.

Deposits of iron ore are known to exist at a number of points in the northwestern portion of the state, chiefly along the borders of the great hill-mass. On Fig. 63 are indicated the position of nine such deposits, of which three, namely Gurumaishini, Okampad, and Badampahar, are of major importance. The smaller deposits are miniature reproductions of the larger ones, all being of the same general type.

The Gurumaishini deposit is the present scene of operations of the Tata Iron & Steel Co. It is now connected by 45 miles of branch railroad with the Company's works at Kalimati, as shown on Fig. 63. Gurumaishini peak, rising about 2,000 feet above the general level of the country to the west (2,958 feet above sea-level), is a conspicuous feature of the landscape. It consists largely of ancient basic intrusives, capped by a huge mass of pure hard iron ore. Similar masses of rich ore, closely associated with Dharwarian banded quartz-iron-ore rocks, sheath its northwestern flanks. At lower levels granite appears.

The basic intrusive was designated "ancient trappoid" in the field. There is unfortunately no detailed description of it. The Dharwars include hard massive iron ore and the usual banded rocks; no other types appear. The granite is a light-colored hornblendic facies. The contact between "ancient trappoid" and granite was nowhere closely observed. Basic dykes with no

[5] Records Geol. Survey of India, Vol. XXXI., 1904, part 3, p. 167.

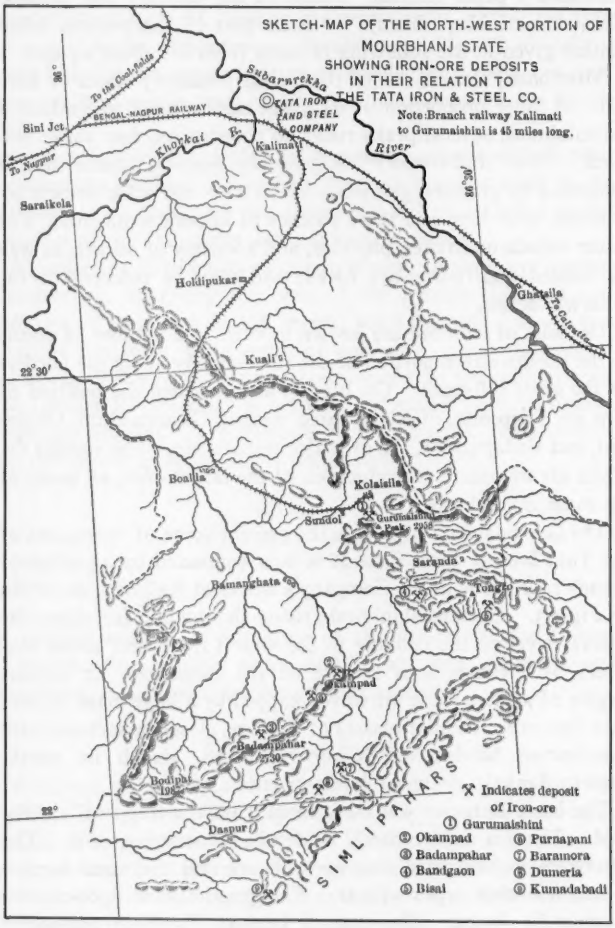

SKETCH-MAP OF THE NORTH-WEST PORTION OF
MOURBHANJ STATE
SHOWING IRON-ORE DEPOSITS
IN THEIR RELATION TO
THE TATA IRON & STEEL CO.
Note: Branch railway Kalimati
to Gurumaishini is 45 miles long.
To the Coal-fields
Subarnrekha
TATA IRON AND STEEL COMPANY
BENGAL-NAGPUR RAILWAY
Sini Jct.
To Nagpur
Khorkai
To Kalimati
River
Saraikela
Holdipukar
Ghatsila
To Calcutta
Kuaiº
Boalia
Kolaisila
Sundoi
Gurumaishini Peak 2936
Sarandi
Bamanghata
Tonga
Kampad
Badampahar 2730
Boripal 1950
Daspur
SIMLIPAHARS
Indicates deposit of Iron-ore
① Gurumaishini
② Okampad
③ Badampahar
④ Bandgaon
⑤ Bisai
⑥ Purnapani
⑦ Baramora
⑧ Dumeria
⑨ Kumadabadi

FIG. 63.

very definite alignment cut the intrusives and probably also the Dharwars.

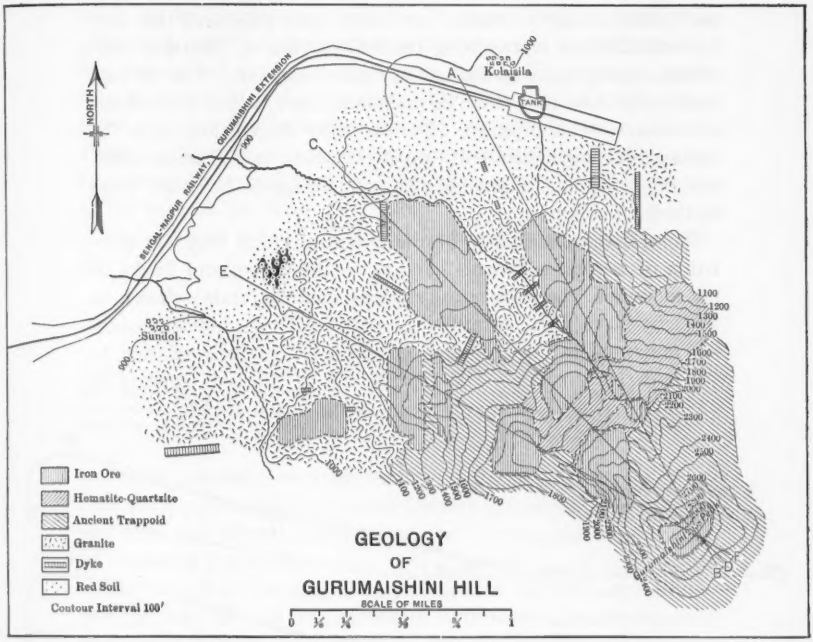


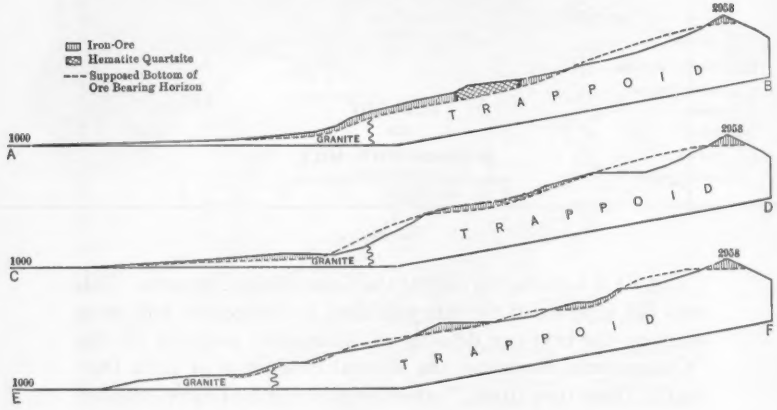
FIG. 64.

Fig. 64 is a geological map of the Gurumaishini deposits. This map has superseded the one published in connection with some notes on the iron ore deposits of Mourbhanj prepared for the "Quinquennial Review of the Mineral Production of India During the Years 1904–1908,"[6] which was the result of more extended examination. The Dharwars are seen lying in great patches on the N.W. flanks of the peak. Every other but the N.W. quadrant shows ancient intrusive rocks. The existence of the ores at

[6] Records Geol. Survey of India, Vol. XXXIX., 1910, p. 110.

and near the contact of a great basic intrusion originally suggested an igneous origin for them. Their similarity to the Dharwar ores of other localities however, and the known presence of Dharwar rocks at other points not far distant, have suggested that they be considered as representing residual patches of Dharwar sediments, resting upon an ancient intrusive basement. It is in fact hard to see how they could be magmatic segregations or products of contact metamorphism. Neither their disposition upon the surface, resting indifferently upon trappoids and granites alike, nor their chemical characteristics would suggest either of these methods of origin.

To test the plausibility of the hypothesis that they are remnants of ancient sediments clinging to the crown and flanks of the mountain, the three cross-sections (natural scale) shown in Fig. 65 have been carefully prepared. These indicate nothing unnatural in the proposed interpretation of their relation to the underlying rocks. The average dip of the beds appears to have been about 10°, the direction being to the N. W.



CROSS-SECTIONS OF GURUMAISHNI, LOOKING NORTH-EAST

SCALE OF MILES

0 ⅛ ¼ ½ 1

FIG. 65.

Such a hypothesis postulates a shallow depth for the ores. Even so, the quantities must be immense. The actual surface area covered largely by massive outcrops, as shown in Fig. 64 totals up to roughly nineteen million square feet in horizontal projection, and we may therefore well estimate at least fifteen million tons of ore for every ten feet in depth. The average depth may be nearer fifty than ten feet. On Gurumaishini peak alone there are probably between four and five million tons. In addition to the ore in place, there are immense blankets of rubble-ore, amounting to several hundred acres, spread over the low ground at the base of the hill.

The analyses given in Table II. indicate the character of the ore.

TABLE II.

	Fe, Per Cent.	SiO_2, Per Cent.	S, Per Cent.	P, Per Cent.
Solid and float ore, 11 samples.....	61.85	4.08	0.036	0.135
Float ore, 20 samples.....	61.46	3.34	0.036	0.048
Solid ore, 10 samples.....	64.33	1.64	0.021	0.075

A number of complete analyses proved the absence of titanium, chromium, zinc, nickel and cobalt (except in one case where 0.090 per cent. was found), copper, lead and baryta; and the presence of arsenic in traces only.

The deposit at Okampad is very similar to that at Gurumaishini. A huge mass of rich ore, associated with banded quartz-iron-ore rock and a dense blackish quartzite, rests upon the flnks of Okampad peak, the latter consisting of "ancient trappoid," with granite at the lower levels and in the flat country to the west. The largest single ore-body covers 300,000 square feet in plan, showing at one point a scarp about 300 feet high. In addition to this there are several smaller ore-bodies and over 150 acres of rubble-ore float. An average analysis showed: Fe, 67.65 per cent.; SiO_2, 1.58 per cent.; P, 0.043 per cent.; S, 0.012 per cent. A 13-mile railway will connect Okampad with the present Gurumaishini railway.

The Badampahar deposit lies eight and one-half miles S.W. from Okampad. Here a great body of massive ore, about 1,500,-

000 square feet in plan, crowns Badampahar peak and extends along the crest of the range. Extending downwards toward the N.W. are numerous smaller outliers, as well as immense areas of rubble-ore float. Banded quartzites and quartz-iron-ore rocks are abundant associates. The underlying mountain mass was seen to be charnockite, with granite in the lower levels to the northwest.

The manner of occurrence of the Okampad and Badampahar deposits is without doubt the same as that of Gurumaishini. The same is true of the six minor deposits indicated on Fig. 63 and numerous others not recorded.

Review and Discussion.

We have seen that all the more important iron ore deposits of India are closely associated with ancient unfossiliferous sediments, corresponding in their stratigraphical relations to the Huronian rocks of North America. Only two of these deposits, namely those of the Dhullee-Rajara hills and of Mourbhanj State, are of proved great commercial value today, though it is quite possible that others still remain to be discovered.

The ancient sediments include schists, slates, phyllites, quartzites, and occasional limestones; but the characteristic member, and the only one of economic interest, is a quartz-iron-ore rock. This ranges from dense white to bluish quartzite on the one hand to pure iron ore on the other; intermediate phases include many varieties of banded ferruginous quartz rocks, not infrequently possessing a strikingly beautiful wavy or crenulated ribbon-like structure, and sometimes schistose. The ore-bodies range from mere films to immense tabular lenses, the longer dimensions always conformable with their siliceous neighbors. The walls are generally not sharply defined. The lenses feather out on their strike, only to come in again somewhere further on.

The ores are generally hard and massive. More rarely, as at Jubbulpore, they are laminated or micaceous, when they are usually more directly associated with slates or phyllites than with the quartz member. These varieties, owing to their physical

structure, do not have the same economic value as the hard ores.

Large areas buried in rubble-ore float are found at some points, notably in Mourbhanj state. Occasional lateritic accumulations on or near the ore-bodies are rich in iron.

There has been a temptation to attribute these ores to igneous origin. They are neither magmatic segregations, nor contact metamorphic products. But a theory was at one time advanced that they were derived through extreme metamorphism, and consequent migration and concentration of the ores, out of basic igneous flows. Their bedded nature was recognized, while the presence of garnet, amphibole, grünerite, etc., was adduced to prove their igneous origin. The derivation of these comparatively rare minerals out of aluminous and other constituents of ancient sediments however would appear to be a more tenable hypothesis than any conception of metamorphism so intense as to induce rock-flowage and wholesale migration. These beds have unquestionably undergone a certain amount of metamorphism, but it is doubtful that they have at any time been deeply buried, and they are frequently only gently folded.

The most natural hypothesis regarding the genesis of the ores is that they are the more or less direct products of primary sedimentation. They were probably not deposited in the form of carbonate, since there is little or no evidence of secondary concentration, either in the character or position of the ore-bodies. Except for very occasional lamination, the ores are dense and massive, neither they nor their wall-rocks showing any appearance of slumping. Nor do they occur in pitching troughs or upon impervious basements, or in association with possible trunk-channels of underground circulation. Carbonate rocks are comparatively rare, and are not associated with the massive ores. It would appear therefore that the ores were originally laid down as ferric hydrates and have since suffered little change beyond dehydration, consolidation, and to some extent deformation.

It is evident that in their stratigraphical relationship and their universal association with banded quartz-iron-ore rocks (banded jaspers), these deposits suggest an analogy with those of the Lake Superior ranges. The resemblance stops at the ore-bodies

themselves however, since these are not secondary concentrations, but the products of original sedimentation. In this last respect, as well as in their associations, they are strikingly like the pre-Cambrian iron ores of Brazil. In fact one is almost tempted to apply the Brazilian terms *itabirite* to the quartz-iron-ore beds, *jacutinga* to the laminated and micaceous ores occurring within phyllites, and *canga* to the surface accumulations of rubble-ore float and rich laterite. And in their genesis they give rise to the same problems concerning topographic, climatic and other conditions which made possible the deposition of such immense thicknesses of sediments extremely rich in iron.

Much the same problems are confronted in a study of the genesis of the Clinton ores of the United States, the Wabana ores of Newfoundland, and the Minette ores of Luxembourg and Lorraine, all of which are now recognized to be of primary sedimentary origin. Interesting differences between these younger, frequently fossiliferous, sedimentary deposits and their ancient non-fossiliferous prototypes of Brazil, India, and (to a less extent) Lake Superior, lie (1) in the generally greater thickness of the latter; and (2) in the universal association of the latter with the peculiar banded ferruginous jaspilites, etc., which are absent from the former. These differences may be due in part to conditions existing in ancient times which have never been exactly repeated, at least not to the same degree; and in part to metamorphic changes brought about through more intense consolidation in conjunction with tremendous periods of time. In their essentials, it seems probable that all these sedimentary ore deposits, both young and old, have owed their origin to more or less similar circumstances. The exact nature of the circumstances can only be conjectured.

SOME TOPOGRAPHIC FEATURES OF SIBERIA.

C. W. Purington.

The portion of Siberia treated of in the following paper is mainly that comprised between the western border of the Altai and the head waters of the Amur River on the east. References are also made to those portions of eastern Russia generally included under the name of the Ural Region.

From the northern border of the Caspian Sea northward to the Artic Ocean extends the broad and poorly-defined series of low mountains and hills known as the Ural Chain. To the eastward from the Caspian extends the enormous Steppe of Central Asia, on the eastern border of which, in the vicinity of Kashgar, the main orographic line of the Altai makes its appearance. The northeast direction of this great divide is exceedingly well marked through Siberia even to the Pacific coast. The Ala-Tau and Sayan ranges on the Russo-Chinese frontier mark its course at the western part, and its line of continuation is taken up farther to the northeast by lower ranges. To the northeast of the Baikal Lake the ancient line of disturbance is continued and marked by the course of the Verkny Angara river. The river Lena north of Irkutsk, follows a northeast course in direct continuation of the line of the Sayans.

The Altai line of disturbance, as it may be called, traceable with a fair degree of continuity for over 4,000 miles, partakes of that continental character possessed by the great north and south mountain uplift of the American Continent. Within the limits of this great range in Asia may be found almost every variety of mountain structure.

The prevailing characteristic of Siberian mountain topography is that of extreme monotony. With the exception of certain serrated ranges in the Altai in the southern part of the Tomsk Government, the higher mountains of Siberia have mainly

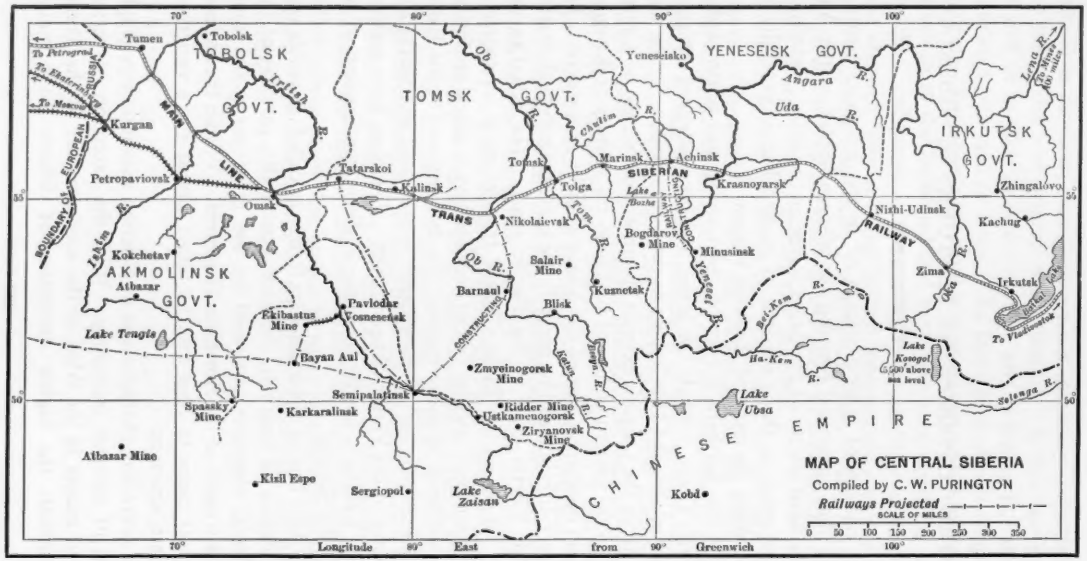

TOBOLSK GOVT.
TOMSK GOVT.
YENESEISK GOVT.
IRKUTSK GOVT.
AKMOLINSK GOVT.
CHINESE EMPIRE
MAP OF CENTRAL SIBERIA
Compiled by C. W. PURINGTON
Railways Projected
SCALE OF MILES
0 50 100 150 200 250 300 350
Longitude East from Greenwich
Tobolsk
Tumen
Kurgan
Petropaviovsk
Omsk
Tsarskoi
Kalinsk
Tomsk
Tolga
Marinsk
Achinsk
Krasnoyarsk
Yeneseisko
Nikolaievsk
Barnaul
Salair Mine
Kuznetsk
Bogdarov Mine
Minusinsk
Nizhi-Udinsk
Kachug
Zhingalovo
Irkutsk
Zima
Kokchetav
Atbasar
Pavlodar
Vosnesensk
Ekibastus Mine
Bayan Aul
Lake Tengis
Blisk
Zmyeinogorsk Mine
Semipalatinsk
Spassky Mine
Karkaralinsk
Ridder Mine
Ustkamenogorsk
Ziryanovsk Mine
Lake Ubsa
Atbasar Mine
Kizil Espe
Sergiopol
Lake Zaisan
Kobd
Lake Kosogol 5,500 above sea level
To Vladivostok
Irtish R.
Ob R.
Yenesei R.
Angara R.
Lena R.
Uda R.
Chulym R.
Tom R.
Kia R.
Oka R.
Selenga R.
Ba-Kem R.
Bel-Kem R.
Trans-Siberian Railway
Main Line
European Russia
Boundary of European Russia
To Petrograd
To Ekaterinburg
To Moscow
To Minusinsk 100 miles

FIG. 66.

rounded forms. The observer is everywhere struck with the planed-down appearance of the country. There is almost an entire absence of sharp or accentuated forms. Such topographic conditions can have been produced only by erosion extended over an immense period of time.

Both in the Ural and in the Altai evidence points to former mountain building on a great scale. Even the vast plains, denominated Steppe, extending in the longitude of the Ural from the vicinity of the line of the Trans-Siberian Railway to the Caspian, are, as the strict geographer would use the term, mountains, but so old as to have entirely lost the character of such.

The main impression obtained from journeys in many parts of Siberia is that the dome is the most characteristic mountain form. Considering the central portion of Siberia successively from west to east, the Ural District, and the following Kirghese Steppe region, represent the portion of greatest erosion.

Leaving out of consideration the northern tundra district, north of the 64th parallel, the great mountain mass may be said to begin from the longitude of Semipalatinsk and to reach its culminating point in the Altai-Sayan range which divides Siberia from the Chinese Empire.

Peaks of 10,000 to 12,000 feet characterize this range, attaining their greatest height in the south part of the Tomsk Government and to the west of the Yenesei River. The valleys between these high peaks are occupied by glaciers and their summits are covered with practically perpetual snow.

The district with which the writer is most familiar is that to the north of the Lake Baikal, as far as the 62d parallel, and to the east of Baikal as far as the Sea of Okotsk.

No satisfactory explanation has been advanced up to the present, for the remarkable earth cleft occupied by the Baikal Lake.

It is noteworthy that this cleft extends in a direction about N. 40 degrees E., and is practically parallel with the stretch of the Lena River, lying about 200 miles to the west of it.

From the north end of the Baikal extends the River Verkny Angara, a continuation of the northeast cleft, and it is reported by recent Russian expeditions that a great plateau is sharply cut

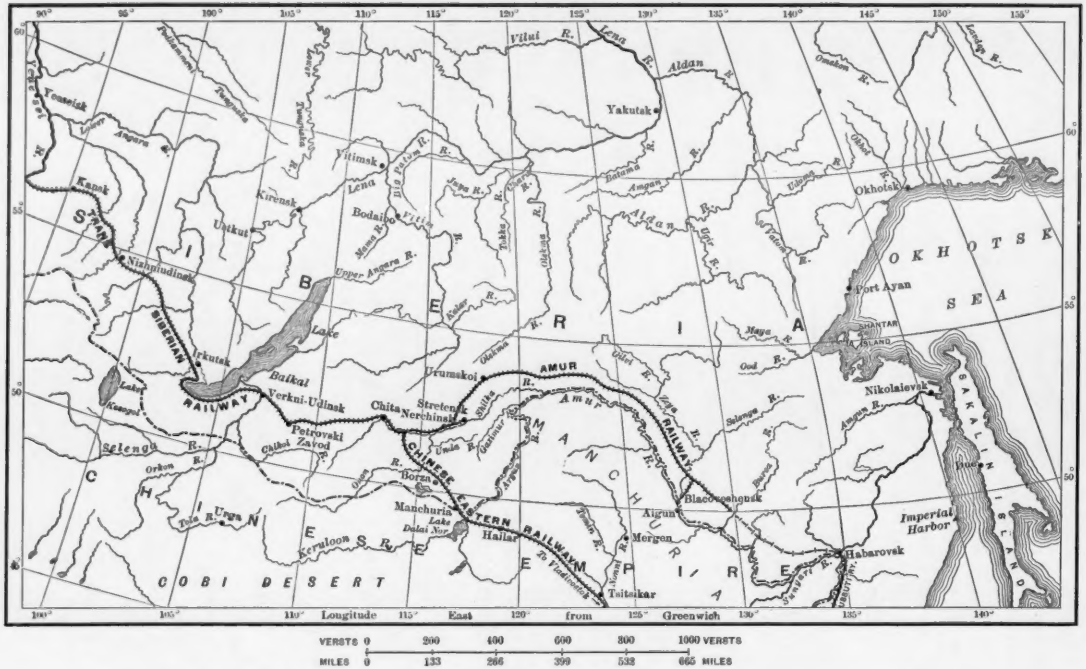


FIG. 67. Map of Eastern Siberia compiled from Russian Sources by C. W. Purington, June, 1915.

by the Angara and Kichera Rivers. The walls of the cañons in which these rivers run are from 1,000 to 1,500 feet in height and nearly vertical. The drainage represented by them has been superimposed on another drainage which has entirely different origin. Gravel plains and river courses occupy the top of the ancient plateau, and are sharply cut by the modern streams. Still farther north, in the so-called Lena Gold Mining District, lying

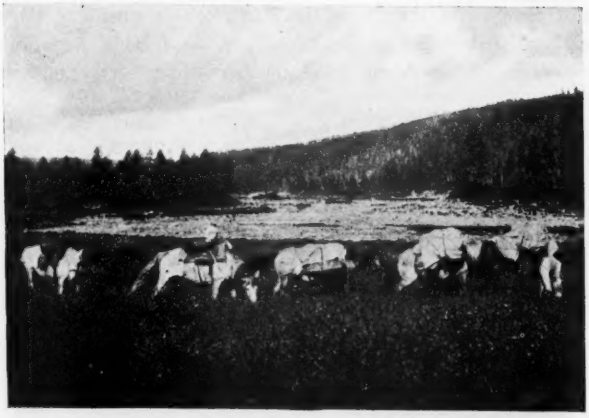


FIG. 68. Prospecting for gold. Anangra River Lena District, Siberia.

between the Vitim and Lena Rivers, the plateau topography lying at an average elevation of 3,500 feet above the sea, is extremely well marked. Here again the modern streams have cut into the ancient gravel plains.

The courses of the modern streams, while generally parallel to the ancient rivers, frequently show evidence of having had different directions, and they do not occupy coincident valleys.

Still farther toward the northeast, between Olekminsk and Irkutsk, the Lena River takes again the prevailing northeasterly direction for a distance of some 500 miles.

Taking the Lena River as the northwestern boundary, and the Amur as the eastern boundary, it will be noted that the territory,

FIG. 67. Map of Eastern Siberia compiled from Russian Sources by C. W. Purington, June, 1915.

500 miles in width and 1,200 miles in length, is characterized by parallel ranges of well-eroded mountains interspersed by river valleys, having the same northeast direction. Only occasionally do the streams cut across these prevailing directions. The ranges flanking the Baikal are succeeded to the east by the Yablonoi or "Apple" Mountains, which are continued in the northeast extension by the Stanovoi range to the shore of the Okotsk Sea.

The principal rivers from west to east, namely, the Bargusin, the Upper Vitim, the China, the Muya, the Olekma, the Tungir, nearly all tributaries of the Lena; and the Ingoda, and Shilka, tributaries of the Amur, have the prevailing northeast course.

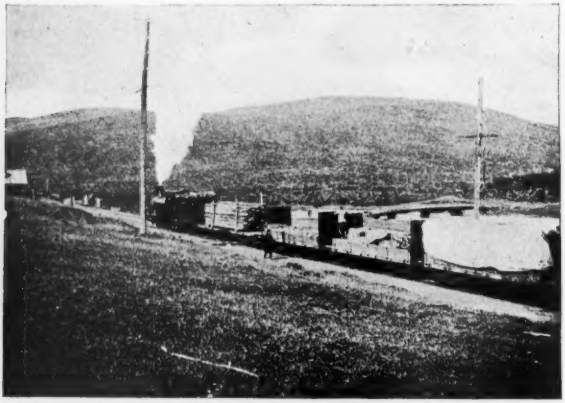


FIG. 69. Topography of the Vitim River drainage. Lenskoi narrow gauge railway.

The Nerchinsk District of the Upper Amur drainage, occupied by the Yablonoi Mountains, has a most distinct plateau character. As the name implies, the hills and elevations which rise above the general level have a dome-like form. Approximately on the line of the 54th parallel, a most striking series of ancient river channels exist elevated above the present streams and extends from the east shore of Baikal in the Bargusin District eastward, as far as the River Argun on the west border of Manchuria.

Russian geographers have made thorough studies of the prin-

cipal lines of orographic disturbances, but appear to have neglected a study of the ancient river channels.

So far as the writer is aware, the tract of country comprised between the 50th and 60th parallels of latitude and the 110th and 120th degrees of longitude, an area of approximately 240,000 square miles, is practically all characterized by a vast system of

FIG. 70. Vitim River Bank Bodaibo, Vitim District, Siberia.

ancient river channels occupying a plateau which has been subsequently dissected by present river courses. This affords a field for geographers, practically untouched and unexplored.

The mapping of these ancient river courses might lead to economic results of no small importance, as the region is one of gold-bearing gravels and has a copious water supply.

In the district of the middle Vitim which has been long celebrated as a gold producing country, the domes rising above the main plateau are extremely characteristic and are known as goltsí ("balds"). The writer has noted that these *balds* in such widely and separated areas as the middle Vitim, the Central Altai, and the district lying to the south of Nerchinsk, near the Manchurian border.

The great extent of these, including as it does whole mountain ranges hundreds of miles in length, is one of the most remarkable

FIG. 71. South of Vitim River. 300 miles north of North End of Baikal Lake.

examples of topographic monotony which the earth's surface presents.

In respect of water courses, systems of drainage, river systems, the same uniformity of conditions prevails throughout north and central Siberia.

The most noticeable features in connection with both the large and the small streams are the extraordinary length, the uniformity in width for long distances, and the absence of numerous tributaries near the source. The absence of grade is accounted for in part by the lack of great elevations. The present streams appear for the most part to be filling rather than cutting their channels. In other words although the streams have cut in many cases to depths of 150 ft. or even more below the level of the secondary elevation referred to, they for some cause appear to have sus-

pended this action, and wander about with very light grades in the midst of immense plains of gravel. These are typical flood-plains, and are generally of a width about ten times that of the streams which traverse them.

It may be said in general that the part of Siberia, south of the 58th parallel, presents no evidences of glaciation. This statement

FIG. 72. The Byeduk Southern Altai.

excepts the present glaciers in the highest mountains of the Altai. On the other hand, the region of the Lena north of Bodaibo presents glaciation phenomena which are thought by Russian geologists to be of widespread character.

In the unglaciated portions of the Altai and Baikal regions, the stream valleys are characterized by generally shallow depth. It is rare to find that the depth of the flood-plain of the alluvium reaches over forty feet in the lower Amur valley. The writer has noted flood-plains of ten miles in width where the depth of the alluvium would not exceed fifty feet. This is in marked contrast to some of the great alluvial of the western United States, as for example, in Montana and California, where the depth may be reckoned in hundreds of feet.

THE ORIGIN AND OCCURRENCE OF CERTAIN CRYSTALLOGRAPHIC INTERGROWTHS.

JULIUS SEGALL.

A relationship of minerals which is commonly referred to crystallographic or micrographic intergrowth is a feature of their paragenesis. There is no uniform opinion as to the significance of these intergrowths. Laney,[1] who first recognized them in sulphide ores, believes that the crystallographic intergrowth of bornite and chalcocite of Virgilina is evidence of the contemporaneous origin of these minerals. Gilbert and Pogue[2] hold that the graphic intergrowth of bornite and chalcocite of the North Mount Lyell Mine, Tasmania, shows clearly the contemporaneous development of these two minerals. Ransome[3] suggests that secondary processes may produce apparent intergrowths which would be difficult to distinguish from contemporaneous intergrowths. Rogers,[4] who discovered such intergrowths in Butte ores, states that the so-called graphic intergrowths of bornite and chalcocite is but an irregular replacement of bornite by chalcocite.

The assignment of intergrowths of sulphides to contemporaneous solidification of the minerals from solution is undoubtedly due to the resemblance of the peculiar patterns formed by the sulphides to those of quartz and orthoclase in graphic granite. The micropegmatitic intergrowths of these silicates are supposed

[1] Laney, F. B., "The Relation of Bornite and Chalcocite in the Copper Ores of the Virgilina District of North Carolina and Virginia," ECON. GEOLOGY, Vol. 6, p. 408.

Graton, L. C., and Murdoch, J., "The Sulphide Ores of Copper; Some Results of Microscopic Study," *Trans. A. I. M. E.*, Vol. 45, p. 77.

[2] Gilbert, C. C., and Pogue, J. E., "The Mount Lyell Copper District of Tasmania," *Proc. U. S. Nat'l Mus.*, Vol. 45, p. 616.

[3] Ransome, F. L., "Copper Deposits near Superior, Ariz.," U. S. G. S. Bulletin 540, p. 152.

[4] Rogers, A. F., "Secondary Sulphide Enrichment of Copper Ores, with Special Reference to Microscopic Study," *Mining and Scientific Press*, Oct. 31, 1914, p. 686.

to represent contemporaneous separation from solution. Similar structures marking the final solidification of solutions are exhibited at the eutectic point of a great many alloys.

In the course of this investigation several new examples of micrographic intergrowths were discovered, and some evidence was obtained that some of these intergrowths may be of secondary origin.

The specimens under consideration were examined both megascopically and microscopically. In the microscopic examinations polished surfaces were employed and the specimens were studied by reflected light. The minerals were determined by means of physical and chemical tests. Particular care was taken in the identification of bornite, as it had an important bearing on the problem. The appearance of bornite sometimes approached that of covellite, and in case of doubt the mineral in question was compared with a known polished surface of covellite.

An interesting series of relations of bornite to chalcocite were found in chalcocite ore from Butte, Mont. The samples were collected by Mr. Lynn Martin from the Leonard shaft at the depth of 1,845 and 2,200 feet. A megascopic examination of the specimens from this mine shows that the chief constituent of the ore is massive chalcocite. Distributed through the chalcocite are grains of bornite varying in size up to one eighth of an inch in diameter. The other recognizable minerals are pyrite, enargite, and quartz. Under the microscope the most notable feature of the polished surface of the specimen from the 2,200-foot level is the symmetrical distribution of the chalcocite and bornite (see Plate XIII Fig. 1). The chalcocite, represented by the light-colored lath-shaped figures, forms triangular areas which are filled by the bornite. The corresponding angles of the triangles are constant throughout the field of observation, and it seems clear that the triangles are the expression of some definite crystallographic relation. They suggest directions of cleavage and twinning. Gilbert and Pogue[5] developed a triangular pattern by etching chalcocite with nitric acid. These investigators refer to the lines limiting these patterns as characteristic cleavage lines.

[5] *Op. cit.*, p. 1.

EXPLANATION TO PLATE XIII.

FIG. 1. Leonard Mine, Butte, Montana. Crystallographic intergrowth of chalcocite (*c*) and bornite (*b*). The crystallographic directions are assigned to the chalcocite. The bornite presumably developed along the existing directions thus giving rise to the triangular patterns. Magnification: × 700 (approx.).

FIG. 2. Leonard Mine, Butte, Montana. Relation of replacement to open fractures. The dark areas of bornite (*b*) on both sides of the black strip representing the fracture, are assumed to show the replacement of chalcocite (*c*) by bornite. Magnification: × 400 (approx.).

FIG. 3. Leonard Mine, Butte, Montana. Illustrated relation between fracture and replacement along crystallographic directions. In the lower half of the photomicrograph the triangular pattern extends from the fracture downward. Magnification: × 350.

FIG. 4. Leonard Mine, Butte, Montana. This photomicrograph shows that the replacement of bornite (*b*) by chalcocite (*c*) has been greater below the fracture than above it. Magnification: × 350 (approx.).

FIG. 5. Leonard Mine, Butte, Montana. Illustrates the tendency of the massive bornite (*b*) to develop along the three crystallographic directions. Magnification: × 700 (approx.).

FIG. 6. Leonard Mine, Butte, Montana. Suggests that the irregular forms of bornite (*b*) in the lower part of the photomicrograph are the continuations of the regular triangular forms of the upper part. Magnification: × 350 (approx.).

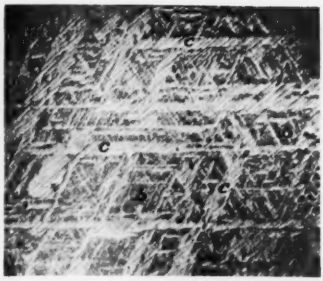


FIG. 1.

FIG. 2.

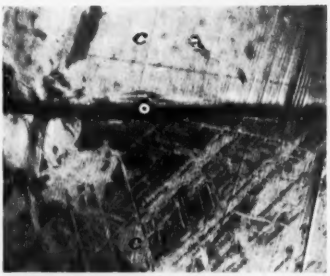


FIG. 3.

FIG. 4.

FIG. 5.

FIG. 6.

Ray,[6] who obtains a microphotograph showing a structure similar to Fig. 1, concludes that the chalcocite has "purified" along what he terms crystallographic planes.

Graton and Murdoch[7] obtain minute partings in three directions by etching massive chalcocite ore from the Bonanza Mine, Alaska. The same results were obtained by them by etching synthetic chalcocite, produced by fusion of copper and sulphur. They also interpret these partings as cleavages of the chalcocite. From the foregoing it appears that the patterns produced by the so-called cleavages along three directions are characteristic of chalcocite. The first impression gained from Fig. 1 is that the chalcocite has developed along three directions within the bornite; this, however, is improbable, as these three crystallographic directions are assigned to the chalcocite. It seems more probable to suppose that the bornite developed along the existing directions and thus gave rise to the triangular pattern. The transformation from chalcocite to bornite was probably accomplished by metasomatic replacement. This change is suggested by Fig. 2. The path of the replacing solutions was a small fracture, indicated by the black strip which extends horizontally through the photograph, from which the chalcocite was attacked on both sides. Replacement probably began along the minute partings of crystallographic directions. It gradually proceeded, changing the cross barriers of chalcocite to bornite, until the whole mass of the former was entirely replaced by the latter. The dark areas of bornite on both sides of the fracture are assumed to show this complete metasomatic replacement. Where the change had reached an advanced but not completed stage the chalcocite appears in needle-like forms arranged in one direction only. Where the replacement had been only partly completed the crystallographic features were retained in two, or in all three directions.

The intimate relation existing between the fractures and replacement along the crystallographic directions is shown more

[6] Ray, J. C., "Paragensis of the Ore Minerals in the Butte District, Mont.," ECON. GEOL., Vol. 9, July, 1914, p. 479.

[7] Graton, L. C., and Murdoch, J., "The Sulphide Ores of Copper; Some Results of Microscopic Study," *Trans. A. I. M. E.*, Vol. 45, p. 79, Figs. 27 and 29.

clearly by Fig. 3. In the lower part of this photomicrograph the dark bornite areas within the triangular chalcocite outlines extend up to the black strip representing the fracture. Above the fracture the light gray area of chalcocite has not been affected. The replacing solutions, coming through the opening, apparently confined their activity to one side. Fig. 4 also represents a case in which the activity on one side of the fracture has been greater than on the other. The replacement, while more advanced in one direction, is not nearly so complete as in the other; the larger area of bornite still includes many needles of chalcocite.

The relation of replacement to defined openings is clearly illustrated by Figs. 2, 3 and 4, and it seems plausible to suppose that these openings may vary in size even to minute fractures that can not be detected with powerful magnification. Sub-microscopic partings existing between planes of crystallographic directions undoubtedly allow the access of altering solutions. By such access there may be developed within the chalcocite a crystallographic intergrowth of bornite and chalcocite that has no connection with visible fractures. This feature is illustrated by Fig. 5.

The transformation of chalcocite to bornite requires the addition of iron. That the solutions which affected the alteration carried iron is suggested by the presence of pyrite in some of the fractures from which the bornite extends in one or both directions. Where found, the pyrite is usually in the form of stringers within the openings, and it is clearly younger than the bornite. The age of pyrite and its relation to openings suggests that the solutions which formed the pyrite probably furnished the iron for the transformation of the copper sulphides.

The bornite that lines the fractures and extends from the openings into the mass of chalcocite is apparently of secondary origin. Consequently it follows that the triangular pattern produced by the replacement of chalcocite by bornite is also secondary. The shapes of the triangles composing the pattern may vary in the different parts of a specimen, depending on the orientation of the section to the crystallographic structure of the chalcocite.

In the change from the crystallographic intergrowth of bornite

and chalcocite to the massive bornite there is a series of stages in which the bornite assumes various shapes. In the first stages of replacement the action is chiefly along crystallographic directions and the chalcocite is broken up into lath-shaped forms (see Fig. 1). As the process continues these laths of chalcocite become narrower and narrower until they are entirely transformed into bornite. The replacement proceeds at an unequal rate in the three crystallographic directions, and grains of bornite are developed, which while irregular in outline tend to conform with the three directions. The latter feature is illustrated by Fig. 5. In the upper left-hand part of the photomicrograph the dark patches of bornite (*A*), still retain one or more of the three crystallographic directions. The dark patches of bornite to the right of the central triangular form (marked *B*) also show a tendency to preserve these directions. The relation of the regular to the irregular intergrowths is suggested by Fig. 6. In the lower part of the photomicrograph the irregular figures (*A*) appear to be the continuations of the upper triangular forms. To the right (*B*) are the characteristic patches of bornite as they appear when a number of the smaller irregular forms are merged into one. This feature, which is more clearly expressed in Plate XIV Fig. 7, is by far the more common of the two. As with the regular triangular forms, the irregular ones are in part at least modified by the orientation of the specimen with reference to its crystallographic directions. Since the bornite which forms part of the intergrowth is secondary it is evident that the pattern developed by the intergrowth of bornite and chalcocite is also secondary.

The occurrence of another intergrowth of bornite and chalcocite was found in a sample furnished by the U. S. National Museum. The specimen was labelled Silver Copper Ore, Bevelheymer Mine, Peavine District, Washoe Co., Nev. Most of the sample is covered with a thin coating of chrysocolla. A fresh surface exhibits chalcocite of exceptionally brilliant luster. In addition to these two minerals the microscopic examination of the unetched polished surface reveals the presence of bornite which constitutes about 5 per cent. of the specimen. The chalcocite appears silvery white and the bornite has the characteristic

EXPLANATION TO PLATE XIV.

FIG. 7. Leonard Mine, Butte, Montana. Characteristic patches of bornite (*b*) as they appear when a number of smaller irregular forms are merged into one. Magnification: × 700 (approx.).

FIG. 8. Bevelheymer Mine, Washoe Co., Nevada. Topical intergrowth of bornite (*b*) and chalcocite (*c*). Magnification: × 250 (approx.).

FIG. 9. Kristeid, Norway. Intergrowth of galena (*g*) and tetrahedrite (*t*). At the base of the galena it forms an irregular contact with chalcopyrite (*cy*). Magnification: × 700 (approx.).

FIGS. 10 and 11. Elkhorn Mine, Jefferson Co., Nevada. Galena (*g*) and tetrahedrite (*t*) forming patterns which resemble characteristic branching intergrowths. Magnification: × 700 (approx.).

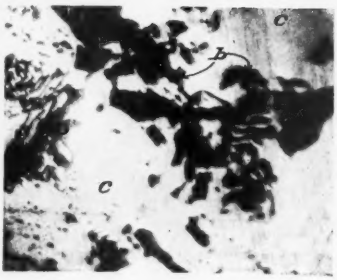


FIG. 7.

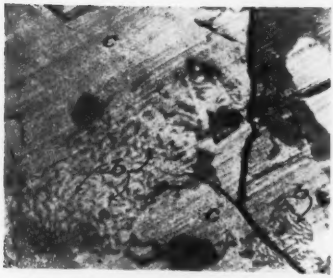


FIG. 8.

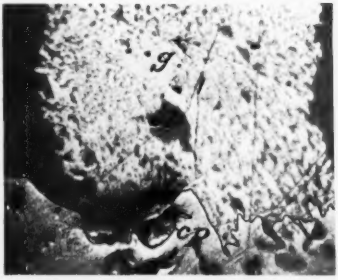


FIG. 9.

FIG. 10

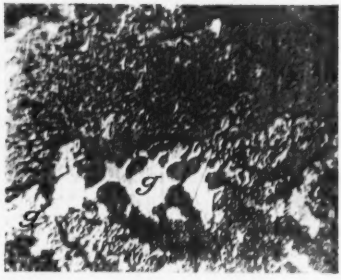


FIG. 11.

lavender color. The chrysocolla has a dark green color and is largely confined to the fractures. The relation of chalcocite to bornite is illustrated in Fig. 8. The bornite, the darker of the two main constituents, has the characteristic branching form assumed to be due to the crystallographic intergrowth of the bornite and chalcocite. Similar to the bornite in Fig. 6, the small irregular forms are seen to merge into larger massive patches. The lack of a clearly defined crystallographic arrangement in this specimen prohibits conclusive statements as to the origin of this intergrowth.

The district from which this specimen was obtained produces some gold and silver. Very little is known of the geology of the peavine district. It is known, however, that the veins in which the ore is found are in granites and schists. This information was kindly furnished by Mr. R. W. Fulton, of Reno, Nev.

The intergrowths of metallic sulphides that have been described heretofore are all of copper minerals. It is therefore interesting to note an intergrowth of galena and tetrahedrite. The specimen exhibiting this occurrence was obtained from the Ward Natural Science establishment, and was labelled tetrahedrite, Kristeid, Norway. The sample is composed chiefly of quartz, with which is associated a green schistose mineral, probably chlorite. Next in abundance is tetrahedrite, which occurs as massive patches and small grains in the quartz. Chalcopyrite and a few grains of pyrite complete the list of minerals that can be recognized with the aid of a hand lens. A microscopic examination of the polished surface reveals the presence of galena. The striking feature of the specimen is the intimate intergrowth of the galena and tetrahedrite. The galena, represented by the white mineral in Fig. 9, has the appearance of a sponge, the openings of which are filled with little dark particles of tetrahedrite. Along the contact of the two minerals the galena fingers into the tetrahedrite. At the base the galena forms an irregular contact with chalcopyrite. Since there is no available information as to the origin of the ore it is not advisable to draw any conclusions as to the mode of formation of the intergrowths.

Other intergrowths of galena and tetrahedrite are represented

in Figs. 10 and 11. Both of these are photomicrographs of a sample from the Elkhorn Mine, Elkhorn District, Jefferson Co., Mont., donated by the U. S. National Museum. The specimen is composed of quartz, tetrahedrite, galena, sphalerite, and pyrite. The galena and tetrahedrite are the chief metallic sulphides; under the microscope the former appears silvery white and the latter light gray. The contact between the two minerals is at some places well defined, but at others very irregular in outline. When irregular, the forms assumed by the galena resemble those of the characteristic branching intergrowths. These irregular patterns, as far as examined, are always confined to the contacts, and it appears that they are the result of an uneven gradation from one to the other. Weed[8] in his paper on the Elkhorn mine concludes that the ores have been formed by ascending waters, by replacement of the country rock. To find ore of such pattern replacing limestone was unexpected, since ordinarily such structures are assumed to represent free crystal growth. Bastin[9] finds similar irregular borders between galena and polybasite. He concludes that galena was replaced by polybasite with the development of a very "ragged" boundary. If it were assumed that some of the tetrahedrite of the Elkhorn mine were secondary, the irregular distribution of the galena at the contact could be interpreted as an irregular replacement of galena by tetrahedrite.

From the relations presented in the previous pages it is inferred that intergrowth of sulphides may be formed by secondary processes. These intergrowths may have a close resemblance to what are known as contemporaneous intergrowths. Since the exact nature of the replacing solutions is not known, no inferences can be drawn as to whether the solutions were descending or ascending.

The writer is much indebted to Dr. W. H. Emmons for his helpful criticisms of this paper.

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[8] Weed, W. H., "Geology and Ore Deposits of the Elkhorn Mining District, Jefferson Co., Mont.," 21st Ann. Rept. U. S. G. S., Part 2, p. 496.

[9] Bastin, E. S., "Metasomatism in Downward Sulphide Enrichment," ECON. GEOL., Vol. 8, p. 56, 1913.

DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, Sheffield Scientific School of Yale University, New Haven, Conn. The full name of the author should be attached to all communications.

ORES, MAGMATIC EMANATIONS, AND MODES OF IGNEOUS INTRUSION.

DISCUSSION OF PAPER BY B. S. BUTLER.

Sir: In number 2 (pages 101–122), B. S. Butler publishes a valuable paper on the relation of ore deposits in Utah to the intrusive laccoliths and stocks of that state. The text of his article (page 116) states his belief that "the space occupied by the igneous material constituting the stocks was formed in large part by a pushing aside and doming of the earlier rocks." The author continues:

> "That there has been some stoping and assimilation of the invaded rocks especially associated with the deeper portions of the stocks, seems not improbable, though little evidence of it has been observed and it is not thought to have been an important factor."

On page 119 the author gives an elaborate section expressing his idea of the underground relations for three stocks (cupolas on a much larger intrusive mass). The diagram (like section and stereogram on pages 71–2 of Mr. Butler's Professional Paper on the San Fransisco region in Utah) clearly shows that the country rocks were *not* pushed aside when the stocks were intruded, and it admirably illustrates the cross-cutting, *replacing* character of a typical stock or batholith. The illustration thus squarely contradicts the text. Which is correct?

The answer to this question is obviously vital to the ore-gen-

esis problem, for, if the stock magmas did replace the Paleozoic sediments by stoping, they must have assimilated large quantities of volatile matter contained in limestone, shale, and sandstone. The roof rocks of these stocks may, therefore, be more mineralized than the roof rocks of the Utah laccoliths, partly because the stock magmas had a higher proportion of "resurgent" gases and vapors. The case recalls scores of other recent discussions of ore genesis, wherein authors have ignored the fundamental problem as to the nature and origin of the ore-bearing magmatic solutions, or have treated that problem as having no concern with the mode of magmatic intrusion. Mr. Butler has done good service in pointing out a profound contrast between most laccoliths and most stocks. One must agree with him in holding that the emanation (true differentiation) of ore-bearing solutions from the Utah magmas has usually occurred on a larger scale in the stock than in the laccolith, because the stock generally had a longer magmatic life, as well as greater depth. However, the efficiency of stocks in developing ore bodies may be due still more to the abundance of "resurgent" volatile matter in a replacing magma. As to the "evidence" of stoping, is not Mr. Butler's cross section, if it correctly portrays the underground relations, very excellent evidence? Whither have the missing sediments gone?

REGINALD A. DALY.

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ORIGIN OF CERTAIN ORE-DEPOSITS.

Sir: I have read with interest Professor L. V. Pirsson's communication in the February-March number suggesting certain general considerations favoring the possibility of an igneous origin for the lead, zinc, etc., ores of the mid-Mississippi region of the United States. This interest emboldens me to extract from my notebook certain fragmentary observations and deductions made in 1907, while making a brief inspection of the property of the Federal Lead Company, at Flat River, Missouri. I desire to ac-

knowledge at the outset that this visit constitutes the whole of my personal acquaintance with the mid-Mississippi ore-deposits; that the inspection lasted only a few days, and was naturally the merest reconnaissance. My observations made at that time made me desire an opportunity of further studying this interesting field, which opportunity has not yet presented itself. For my knowledge of the main geological facts of the district I was indebted to the geologists who had studied and mapped the local geology, especially Messrs. Buehler and Crane, who courteously guided me on my inspection. With regard to my observations and conclusions as indicated below, there was, as I recall it, little or no difference of opinion in respect to observed facts, but only as regards deductions therefrom. I give these notes for what they are worth, making no claim for them; but thinking that as the informal thought of a petrographer on the subject had interested me, so the private notes of a reconnoitering field geologist might also be of interest to some.

"The beds usually have a dip of 1°–2°. The hasty trip we took shows numerous, predominatingly strong fractures in the rocks, accompanied by frequent faulting. These faults increase in magnitude, and displacements of 25 and 50 feet are met with, and one—the farthest southwest seen—has a displacement of upwards of 500 feet. These faults, where seen, are always vertical, and mainly strike northwest, though frequent minor east-west faults are noted.

"The map of the underground workings of the main mine of the Federal Lead Company, showing the worked-out stopes, shows that the ore-body had a main N.W. extension parallel to the prevalent faulting, while definite straight minor shoots run in an E.N.E. direction. To one who has studied ore-deposits in limestone in other regions, it is perfectly clear that this shape is due to fracture-zones which have been channels of water-circulation. . . .

"In the underground workings, the ore was not definitely observed to be along distinct fracture zones, although its worked-out form indicates that this is the case. A number of minor, N.W. trending, vertical faults were found (maximum throw six feet) which are plainly post mineral; also strong vertical N.E. fractures (corresponding in direction with the minor noteworthy extensions of the ore-bodies) carry a heavy flow of water, but are post mineral. The assumption is that fracturing (without notable displacement) was followed immediately by ore de-

position, which was caused by solutions circulating along the openings thus formed, and that subsequently the stress continued, causing open fractures and faults. These faults, representing most of the period of dislocation, are absolutely unmineralized, so far as noted. At one locality in the mine a strong water-carrying fissure was observed cutting across a definite shale band in the Bonne Terre dolomite, yet there has been no mineralization whatever. Here we have all the conditions for ore-deposition called for by the prevailing theory; but the facts are opposed. Far from being remarkably active in transporting mineral substances, the waters in these fissures appear unusually inefficient—and always have been, since the post-mineral dislocation—as compared with the superficial underground waters encountered in mining districts like Leadville, Aspen, and Georgetown, in Colorado. These groundwaters at Flat River have apparently had plenty of time for ore-deposition, had this been their function. The age of the post-mineral fault-fissures is not known, but even the heaviest faults are not expressed in the topography, and with the extremely slow rate of denudation prevailing in this country of sluggish streams and flat topography, no very recent date can be assigned to this post-mineral faulting. It is certainly pre-Pleistocene. Therefore theories which appeal to the groundwater circulation, as the agent of ore-deposition, are not applicable. The data indicate that the ores were all deposited at a single definite and very brief epoch, following the initiation of the regional fracturing and was practically entirely finished before the slow growth of the attendant faults had begun. That this epoch of swift mineralization was one of intense activity is evidenced by the immense tonnage of lead mined from these ore-bodies. The origin of the dynamic movements and the ore-deposition are probably closely allied, and a special type of solution must be postulated as the ore-bearing vehicle.

"The ores, disseminated or solid, have been deposited mainly by replacement, as shown by underground examination. Some have formed along cracks and tiny fissures, some apparently along relatively weak beds which have been sheeted and brecciated by the dynamic stresses. The ore as mined is in its original sulfide form; there are no signs of rearrangement, or of more than one period of deposition.

"The limestone and other wall rocks in the mines show no indication of having had their material searched and rearranged by traversing waters. Among the wall rocks beds of glauconite or indurated greensand are found. The glauconite, as shown by thin section, is still in its original state as an undecomposed silicate. Had the rock been thoroughly traversed by searching oxidizing waters (according to the prevailing theory) the glauconite would have been decomposed into iron oxide and

silica (cf. R. A. F. Penrose, Jr., 'Iron Deposits of Arkansas,' Ann. Rept. Ark. Geol. Surv., 1892, Vol. I.)

"The mine examination shows that shale beds have exercised strong precipitative influence on the ore-bearing solutions, as recognized by the local geologists. Usually shale streaks in limestone are bordered by a band of sulphides (galena and iron sulphide), perhaps, more frequently, chiefly on the lower side; frequently on both sides; and sometimes chiefly on the upper side. In a more advanced stage, the sulphides penetrate the shale, and replace it. At the base of the Bonne Terre dolomite, shaly layers become more frequent, and in the upper 15–20 feet above the base (and the top of the La Motte sandstone) there is much greensand associated with the shales. The glauconitic sandstones, however, seem to have exerted no special precipitative influence. This horizon (the lower part of the Bonne Terre) is also the principal ore-horizon of the mines.

"The formula for the locus of an ore body seems to have been: the conjunction of fracture zones, forming circulation channels, with shale beds inducing precipitation.

"The ores consist of mainly pure galena. There is a little calcite, practically no zinc, and a very small amount of iron sulphide (reported both pyrite and marcasite). . . .

"The conclusion reached is that the ore was derived from some source foreign to the observed formations; that the time of ore-deposition was definite and brief, that the conditions were unusual, and the mineralizing solutions different from ordinary ground waters. The only hypothesis which harmonizes with the facts is that postulating the access, for a brief period, of hot highly metalliferous solutions, following and associated with the beginning of dynamic disturbance. What was the cause of this disturbance?"

J. E. Spurr.

Philadelphia, Pa.,
May 13, 1915.

PRE-CAMBRIAN GOLDFIELDS.

At a meeting of the Royal Society of Canada held in Ottawa on May 25, 26 and 27, Mr. J. B. Tyrrell, of Toronto, read a paper entitled "Pre-Cambrian goldfields of Central Canada" of which the following is an abstract.

In this paper gold is regarded solely as a geological unit. Its occurrence in quartz veins, or in rock adjoining those veins, and

the minerals with which it is associated are recorded, but the immediate commercial importance of particular deposits, and the question of abundance of gold in the vein or rock, whether it may contain 1 dwt. or 1 oz. or 100 oz. to the ton is not here considered.

The Classification adopted is very similar to that used by A. P. Coleman and W. H. Collins, but W. G. Miller is followed in using the term Temiskamian for the upper sedimentary member of the Pre-Huronian, and Lawson's term Algoman is used for the igneous rocks which intruded this sedimentary series before the Huronian. The classification is as follows:

HURONIAN. Conglomerate, quartzite, etc.

Great Unconformity.

ALGOMAN. Granite, lamprophyre, albite-diorite, etc.

Intrusive unconformity.

TEMISKAMIAN. Conglomerate, quartzite, graywacke, etc.

Unconformity.

LAURENTIAN. Granite, porphyry, etc.

Intrusive unconformity.

KEEWATIN and GRENVILLE.

Basic igneous rocks and Limestones and other sediments.

COUCHICHING.

The gold-bearing veins are divided into two groups, according as the metal in them is associated with arsenopyrite or pyrite. Then the various occurrences of gold on the Canadian shield are described, beginning at Beaver Lake, in the Province of Saskatchewan, in the west, and proceeding eastward to Hastings County in Ontario and Hurricana in Quebec.

The veins occur in rocks of Keewatin, Laurentian?, and Temiskamian age, but they do not extend up into the overlying Huronian. Wherever the Temiskamian rocks are present and where the veins occur in them, they are newer than them, and the conclusion is drawn that probably all the gold bearing veins are Post-Temiskamian or Algoman, and Pre-Huronian in age.

If this conclusion is correct the Algoman Period would represent a distinct *Chrysogenetic* Epoch in the Pre-Cambrian of the Canadian Shield.

The following conclusions are presented as the results of the investigations.

1. The veins are Pre-Huronian in age, no gold-bearing veins having been recorded in rocks of Huronian age in Central Canada.

2. They frequently occur in both basic and acidic rocks of Keewatin age.

3. Wherever the later Temiskamian rocks are present in association with the Keewatin rocks the gold-bearing veins are clearly determinable as being younger than the Temiskamian series.

4. They are constantly associated with albite-porphyries.

5. These porphyries, etc., may reasonably be regarded as apophyses from batholitic granitic intrusions of Laurentian and Algoman age.

6. The gold quartz veins have not been found, and do not seem to occur in the body of the batholiths of granite or gneiss, whether these are of Laurentian or Algoman age, as evidenced by their absence in the vast areas of hundreds of thousands of square miles in Northern Canada, where those granites alone are well exposed.

7. In the Algoman Period, in which most, if not all, of the gold-bearing veins in the Pre-Cambrian rocks of Central Canada would appear to have been formed, we have a Chrysogenetic Epoch, during which gold rose from the deeper parts of the earth, and was deposited in such fissures as occurred in the rocks at the time, no matter through what agencies those fissures were produced.

8. The existence of a single Epoch in the Pre-Cambrian characterized by the formation and presence of veins carrying such a distinctive and much sought for mineral as gold, should be of great service in assisting in the determination of the age of other formations in these old rocks, where so many other criteria which can be used in the determination of the age of later rocks are not available.

REVIEWS

(1) The Geology of the Northwestern Part of the Wankie Coal Field. By B. LIGHTFOOT, geologist. Geological Survey of Southern Rhodesia, Bulletin No. 4.

(2) The Wankie Colliery and Methods of Working the Coal. By A. R THOMPSON. Geological Survey of Southern Rhodesia, Bulletin No. 4.

(3) The Coal Resources of Rhodesia. By H. B. MAUFE, director Geological Survey of Southern Rhodesia, Bulletin No. 4.

This bulletin contains an interesting description of the Wankie coal field which lies about 68 miles southeast of Victoria Falls. The coal is contained in the lower part of the Karoo system, overlying the Lower Wankie sandstone which is correlated with the well-known Dwyka conglomerate of the Cape Colony region. The Dwyka conglomerate has furnished abundant evidence of glaciation, but so far nothing of this character has been found in the Lower Wankie sandstone.

The only mine in the field was opened in 1903 and since that date has produced 1,366,339 tons, with an output in 1912 of 216,140 tons. The coal is of high rank, its only drawback being a heavy percentage of ash which in the various analyses runs from 6 to 15 per cent. The coal as it comes from the mine is hand-picked and the fine coal is then sent to a washery where about 35 per cent. of the ash is removed. Intrinsically the Wankie coal compares favorably with the best coals of this country and, as it has a fuel ratio (fixed carbon divided by the volatile matter) of over 3 it should be placed in the semibituminous class.

To the geologist one of the most interesting features of this report is the conclusion that the coal is not the result of vegetation growing in place, but of drifted material. As the opposite opinion is almost universally held in this country, the reviewer feels warranted in giving the evidence presented in the report and in discussing it in some detail. The facts that are given as favoring the drift origin are as follows: (1) The absence of any fireclay under the coal bed; (2) the fragmentary character of the organic remains, and (3) the muddy material interbedded with the coal. The same sort of phenomena as those listed above are found in most of the American coal beds, but here they are interpreted in a different way. It is true that the great majority of coal beds are underlain by clay which in general is called "fireclay" and that such

clay usually shows by its character and its contained root fragments that it was at one time the soil in which the coal-forming plants grew, but it is also true that many beds rest directly on sandstone or sandy shale. In such cases are we justified in the assumption that the coal-forming plants could not have grown in the sand and therefore that the vegetal matter must have been floated in? It seems to the reviewer that such an assumption is not warranted, but that the question should be answered by a comparison with present-day conditions. Is the presence of a sandy soil today any bar to the growth of vegetation, provided the supply of moisture is sufficient? Do not trees and shrubs flourish on the clean sands of Florida and farther west and north on the Gulf and Atlantic coasts? Assuredly they do, or else much of that region would be a barren desert. Not only does vegetation flourish today on the sands of Florida, but it has flourished in the past as is attested by the many deposits of peat which lie in immediate contact with clean white sand, and which in time, if sufficiently protected by overlying sedimentary deposits, will become coal. It therefore seems to the reviewer that the lack of fireclay can not be used as evidence in support of the drift origin of a coal bed.

The fragmentary character of plant remains is also a kind of evidence that must be used with care, else it may be very misleading. The broken fragments of plants are almost always found in the shale overlying the coal and, whereas they are undoubtedly indicative of the conditions under which the shale was laid down, they may have no bearing on the problem of the deposition of the coal. According to the swamp theory the deposition of shale, clay, or sand indicates a change of conditions in the old swamp and the influx of a large amount of foreign material. In fact the shale above the coal tells of the passing away of the swamp and the washing in of material from the outside. Under such conditions would it be surprising to find the plants in a fragmentary condition and showing signs of having been transported some distance? But even if the shale is full of broken plant fragments that may have been washed in from the outside, is that any evidence that the coal has had a similar history? Not at all! It may however be argued that the plant remains in the coal itself are fragmentary, thus showing that the coal as well as the shale was washed material. But do fragmentary plant remains in the coal indicate that it has been drifted into place? By no means! According to the swamp theory, the presence of such material merely marks epochs of desiccation in which the material was not submerged at once, but was exposed to the action of the elements and so broken to pieces. The evidence of such epochs is to be found in the layers of mineral charcoal which, in some coal beds, are extremely abundant. The presence therefore of fragmentary plant remains, either

in the coal itself or in the associated shale should not, in the opinion of the reviewer, be held as sufficient evidence of the drift origin of the coal.

The third and last line of evidence is that afforded by "the muddy material interbedded with the coal." If the presence of such material is to be regarded as conclusive evidence of the drift origin, then almost all coals of North America would have to be so classed, for perhaps 99 per cent. exhibit such features. But, although there is no question about the prevalence in most coal beds of material of this kind are we sure that it is being correctly interpreted in the Wankie field and that it is evidence against the origin in situ? Is it not possible today to have such material washed into a swamp in which peat is accumulating and if it is possible today may it not have been equally possible in Carboniferous or Permo-Carboniferous time? Will any one maintain for a moment that geologic processes are inherently different today from what they were in the Paleozoic era? We are therefore forced to conclude that, even in Carboniferous time, fine silt or clay may have been carried into peat-forming swamps, even where they were many miles in extent.

In conclusion, it seems to the reviewer that the evidence submitted is not sufficient to justify the conclusion that the Wankie coal is the result of drifted vegetation, but that, on the other hand, it is entirely in accord with the theory of its origin in situ.

The last paper in the bulletin is of general interest, as it gives a new estimate of the coal resources of Rhodesia by H. B. Maufe, Director of the Geological Survey of that State. This estimate agrees with that in "The Coal Resources of the World" published by the Twelfth International Geological Congress, except that in the bulletin there is an important addition to the figures given in the previous report. The amounts expressed in short tons are as follows:

COAL RESOURCES OF RHODESIA.

Actual reserves (International Congress report)	462,213,000
Probable reserves (International Congress report)	165,449,000
Probable reserve (added by new estimate)	440,920,000
Total	1,068,582,000

A slight typographical error in the International Congress report makes the actual reserves for Massabi as 36,750,000 metric tons whereas it should be 36,720,000 metric tons. MARIUS R. CAMPBELL.

Practical Oil Geology. By DORSEY HAGER. McGraw-Hill Book Company, Inc., New York, 1915.

Almost any one who has had occasion to investigate the geology of a productive oil field, or of prospective oil lands has felt that the character of the work that a geologist performs is understood by very few people.

Particularly has he felt the lack of understanding shown by most drillers and by many of the officers of the oil companies, for it is upon these men that the geologist must rely for much of the information necessary in the successful completion of his work. Many of the operators possess a most hazy idea as to just what a geologist can accomplish and either believe him to be endowed with occult powers that permit him accurately to determine the presence or absence of oil in any spot, or else—and most of them assume this attitude—they resolutely contend that he is purely an impostor who is not worthy of the attention of sensible folks.

It is to describe to the "practical oil man of America" the work of the geologist that Mr. Hager has prepared this handbook, hoping to "bring him to a better understanding of the relation of the geologist to the petroleum industry."

The idea is indeed a praiseworthy one, yet after a careful reading of the book the reviewer wonders whether or not the hopes of the author will be fulfilled, for the book does not appear to be quite the thing one would wish to hand to a skeptical oil man in order to convince him of the value of the geologist to the oil industry. However, as an elementary discussion of the general factors concerning the occurrence of oil and the methods of obtaining it commercially, such as might be read with interest and profit by one who knows but little of the subject, and particularly by one who wishes to estimate for himself the value and probable truth of a prospectus of an oil company the book will prove useful.

In a handbook of 150 pages it is obviously impossible to treat adequately the many phases of geology and of oil production methods discussed by Mr. Hager, and it would appear to the reviewer that the book would have gained much had parts been omitted and other parts been treated more fully. Thus, Chapter VI., on "Factors in Oil Well Drilling," with the illustrations of derricks and tools might well have been left out, for it really contains but little that a good oil well driller does not thoroughly understand. It is questionable also as to whether the list of geologic formations that contain oil (Table VIII.) is of sufficient value or sufficiently accurate to justify its insertion. It is impossible in such a table to do more than list the names of the formations in which oil has been found. The correlations suggested by listing together the oil bearing formations of Wyoming, Texas and California can not be more than most general and are liable to be very misleading. If the formations are to be tabulated at all it would seem to be better to list separately those in the different regions as was done in the case of Oklahoma.

In places the book shows signs of hurried and careless work. This is especially noticeable in Chapter I. in which the section on the "Chemical Composition of Petroleum" is said in a footnote to be "After Clark,

Data of Geo. Chemistry."[1] Following the material that is taken from Dr. Clarke's book are analyses of oil quoted from Bull. 18 U. S. Bureau of Mines; Bulls. 452 and 579 U. S. Geol. Survey; and the Production of Petroleum in 1913, Mineral Resources of U. S., U. S. Geol. Survey, which, to judge from the way they are presented, would appear also to have been taken from the "Data of Geochemistry" Despite the fact that he gives his reader no idea as to where the original tables may be found Mr. Hager is most scrupulous in reproducing the footnotes that accompany the original tables, although these footnotes are not essential and refer to matters that are discussed in other parts of the publications from which he has taken the tables. An example of this occurs in Table VId, which is taken from Bull. 452 U. S. Geol. Survey. A footnote to the table says, "No. 11 here is No. 9 on the map," and the reader must discover as best he can what this map is and where he can find it. Another instance of careless work is shown by fig. 17 which is adapted from fig. 7, Bull. 398 U. S. Geol. Survey. The diagrammatic section shown has been so changed in the re-drawing that the unconformity to which Mr. Hager calls the reader's attention does not appear.

The book, if it fulfills the hope expressed by the author in his dedication, is of value chiefly for the material contained in Chapters III., IV. and V., on "Structural Geology," "Prospecting and Mapping," and "Locating Drill Hole Sites," and indeed it is only the material contained in those chapters that justifies the publication in handbook form. In these chapters are many excellent diagrammatic cross sections that illustrate the general types of structure discussed by the author. Objection might, however, be made that Mr. Hager has drawn too largely from conditions in the California fields, where the structural features are sharply developed, and that he has not mentioned sufficiently the slightly tilted or folded structures of the eastern fields. This part of the book might well have been enlarged by a more comprehensive treatment of the features that he dismisses with brief and somewhat dogmatic statements.

The book contains few typographic errors, the substitution of "moon" for "mono" on page 48, of "tolls" for "tools" on page 98, and three errors in Table XI., being the only ones noted by the reviewer; unless the assertion contained in Table VII. that the Triassic, Jurassic, Lower Cretaceous and Upper Cretaceous are equivalent to the "Comanche or Shastan" be a typographic error.

In the discussion of "Prospecting and Mapping," Chapter IV., the author states that "oil occurs in sedimentary rocks of marine, estuarine and deltaic origin, *i. e.*, beds formed along sea shores, in inland bays, at river mouths, etc." The reviewer is led to wonder why oil is so hesitant

[1] Clarke, F. W., "Data of Geochemistry," 2d ed., Bull. 491 U. S. Geol. Survey, 1911.

to enter beds laid down in fresh water. It may be that it is the author's intention to describe the types of beds in which he believes oil to have been contained originally, but even so his statement is open to criticism.

On the whole the book is a praiseworthy effort to present in elementary form the general principles of geology that apply to the occurrence of petroleum. In many ways the work follows closely the mode of treatment used by Cunningham-Craig in his book entitled "Oil Finding," yet as the illustrations and examples are drawn from conditions in the United States it will doubtless prove of greater service to the American operators.

R. W. PACK.

Preliminary Report on the Clays and Shales of Minnesota. By FRANK F. GROUT and E. K. SOPER. 172 pp., 7 pl., 4 figs. Minnesota Geol. Survey, Bulletin No. 11, 1914.

The first part of the report is devoted to a general discussion of clays, their origin, classification, technology and their physical and chemical properties. A chapter is given over to a consideration of the geology of the state with special reference to clays. This subject is treated clearly and concisely, in a manner not too technical for the average reader. Accompanying this discussion is tabulated information regarding the approximate thickness and the general character of the strata of all the geological formations and any clay bearing values which these formations may possess. Thus a glance at this summary will show that the Benton Shale and the Dakota Sandstone of Cretaceous age contain much high grade clay and fire clay, and that the Maquoketa Shale of Ordovician age contains but little clay shale.

The clays of Minnesota are finally considered by counties, each of the eighty-six counties given space in proportion to the present or future importance of the clay resources. Particularly interesting to the reviewer was an account of the investigation of a Huronian residual clay in Morrison County which gives strong evidence of the presence of bauxite. The texture of the clay varies from a massive white to a ferruginous, highly concretionary red clay. The concretionary material when analyzed showed the presence of 19.81 per cent. of silica and 52.43 per cent. of alumina. Assuming that the silica is all in a combined state and that the clay base is kaolin, a mineral calculation of this analysis shows the presence of 35.60 per cent. of excess lumina or about 48 per cent. of bauxite.

The total production of clay products of all types in Minnesota in 1910 is given at a value of more than $1,900,000.

M. G. EDWARDS.

RECENT LITERATURE ON ECONOMIC GEOLOGY.

COMPILED BY

SIDNEY PAIGE.

METALLIFEROUS.

GOLD.

Gold Fields of Nova Scotia. By W. MALCOLM. Memoir No. 20-E, Geological Survey of Canada, Ottawa, 1912. 331 pp., 42 plates, 24 figures, 2 maps.

A compilation representing not the field work of the author but data gathered from the studies of E. R. Faribault and others and prepared under the direction of the latter.

The gold fields occupy that half of the province lying along the Atlantic coast and extending the full length of the peninsula. The rocks consist of an immense thickness of quartzites (locally called Whin) and slates folded in long east and west anticlines intruded by granite. The ore deposits are in the form of veins which are found aggregated on the domes of the plunging anticlines. The deposition of the ore is dependent on rock structure. During folding there was slipping of the beds one upon another and a fissuring along bedding planes. Deposition of auriferous quartz took place. Two theories have been advanced to explain the ores, one that of lateral secretion of auriferous solutions, the other that the minerals were deposited from ascending thermal solutions. The latter is the more generally accepted theory. The veins resemble the saddle reefs of Bendigo, Australia, which have been mined to great depths. The report contains much detailed information.

PLATINUM.

A Gold-Platinum Lode in Southern Nevada. By ADOLPH KNOPF. Contributions to Economic Geology, 1915; Bull. 620a, U. S. Geol. Survey.

An account of a deposit extraordinarily rich in gold-platinum and palladium. The deposits are siliceous ores carrying a small quantity of bismuth-bearing variety of plumbojarosite, replacing dolomite along a nearly vertical fracture zone.

It is probable that the mineralization followed as a sequel to the in-

trusion of the magma from which granite porphyry dikes of the country are derived.

SILVER–LEAD.

The Main Mineral Zone of the Santa Eulalia District, Chihuahua. By BASIL PRESCOTT. Am. Inst. of Min. Eng., Feb., 1915, pp. 155–198. 1 map, 1 fig.

The ore deposits occur in Cretaceous limestone, folded and cut by several systems of fissures of which only those with a general north-south strike are pre-mineral and control the deposition. The deposits are of two main types: the earlier silver-bearing iron sulphide type, of high grade tabular bodies resembling veins, and the later silver-lead-zinc type occurring in vertical chimneys and horizontal mantas principally as oxides, though some sulphides have been encountered in depth. During oxidation the ore chambers have increased in size owing to the solution of the walls by sulphuric acid generated in the process and a substitution has taken place of nearly one half part by weight of the original constituents of the ore, by newly introduced elements and radicals. Both types are believed to have come from greater depth than those yet reached by mining and their ultimate source is believed to be an igneous rock in contact with the limestone at some horizon below. The deposits are believed to have been formed at great depth as indicated by the proved great range of the silicate minerals, coupled with the absence of igneous rock and by the practically unchanged character of the silver-lead-zinc ores.

Geological Investigations in the Broken Hill Area. By D. MAWSON. Memoirs of the Royal Society of South Australia, vol. 2, pt. 4, pp. 211–319, 31 plates, 1 map, Adelaide, 1912.

The area comprises Pre-Cambrian schists, gneisses, granites and amphibolites: Lower Cambrian conglomerate, slate, and limestone; and Tertiary sandy and clayey beds. There are Paleozoic intrusives of basic rock.

The ore deposits within Pre-Cambrian rocks comprise the important silver-lead-zinc lodes of Broken Hill, and platinum lodes. The genetic connection between granite intrusion, pegmatite dikes as ore bringers and the ore deposits is emphasized. The lodes are of two classes. First, silver-lead fissure veins with carbonate gangue, marked by rich silver antimonides, and second, massive bodies of mixed sulphides accompanied by replacement phenomena. The great Broken Hill lode is of the latter class and is located along a faulted, mineralized anticline. Secondary enrichment has been pronounced. The genetic relations of the lode are discussed and the conclusion reached that they are most probably of Pre-Cambrian age, and connected with the granites.

COPPER.

Texada Island, B. C. By R. G. McConnell. Memoir 58, Geological Survey of Canada. 9 maps, 8 plates, 1 figure. Ottawa, Canada.

Geology and ore deposits are described. The mineral deposits consist of replacement deposits of the contact metamorphic type and a few quartz veins. The former are the most important and may be subdivided in deposits worked for copper and those worked for iron.

The Occurrence of Covellite at Butte, Montana. By A. Perry Thompson. Am. Inst. of Min. Eng., April, 1915, pp. 645–677. 19 figures.

A very detailed account, with many illustrations of polished sections, of the inter-relations of this mineral with other copper sulphides. The covellite is mainly a replacement of enargite by primary ascending solutions. Shows that covellite is widespread at Butte in microscopic quantities.

Geology of the Burro Mountains Copper District, N. M. By R. E. Somers. Bull. Am. Inst. Mining Eng., May, 1915, pp. 957–996. 25 figures.

A detailed study of the copper deposits at Tyrone, N. M. The copper occurs in the mineral chalcocite, produced by downward secondary enrichment of pyrite and chalcopyrite. The replacement of sphalerite also by chalcocite is described. It occurs for the most part in fractured quartz monzonite porphyry.

GENERAL.

Contributions to Economic Geology, 1913, Pt. 1, Metals and Non-metals, except fuels. Short papers and reports, by various authors. Bull. U. S. Geol. Survey, No. 590, 1915.

Mineral Deposits of the Santa Rita and Patagonia Mountains, Arizona. By Frank C. Schrader, with contributions by James M. Hill. U. S. Geol. Survey Bull. No. 582, 1915.

Economic Minerals and Mining Industries of Canada. Mines Branch, Department of Mines, Ottawa, Canada.

A compilation presenting in a popular form a brief sketch of the more important economic minerals and of the mining and metallurgical industries of Canada.

Mineral Resources of Alaska. By Alfred H. Brooks, and others. Report of progress on investigations in 1913. U. S. Geol. Survey Bull. No. 592, 1914.

Moose Mountain District, Southern Alberta. By D. D. Cairnes. Geol. Survey of Canada, Memoir 65, p. 62.

Some Mining Districts in Northeastern California and Northwestern Nevada. By J. M. HILL. U. S. Geol. Survey Bull. No. 594. XIX. plates, 4 figures, 1915.

THEORETICAL.

Persistence of Ore in Depth. By T. A. RICARD. The Inst. of Mining and Metallurgy, Bull. 122, November 12, 1914. 24 pp., 3 figures.

This paper supports the thesis that in general ore bodies will become impoverished in depth. An analysis of the world's great mines, and modern theories of ore deposits are brought forward to uphold this view.

Ore Deposits in and Near Intrusive Rocks by Meteoric Waters. By ANDREW C. LAWSON. University of California Publications, Geology, vol. 8, No. 9, pp. 219–242, 4 figures. October 3, 1914

A reply to critcisms of Professor Lawson's views on ore deposition. The paper holds that the origin of ore deposits in or near intrusive contacts is still an open question. The belief is expressed that the development of ore bodies in contact zones is not a characteristic of batholiths, but only of those minor intrusions which are injected into the earth's crust in the form of laccoliths, sills, etc. The importance of synclinal structure in its bearing on underground water circulation is emphasized and the hypothesis that meteoric waters may play an important part in the formation of contact deposits is supported.

The Constitution of the Natural Silicates. By FRANK WIGGLESWORTH CLARKE. U. S. Geol. Survey Bull. No. 588, 1914.

NON-METALLIFEROUS.

DIAMOND.

The Diamond Fields of Southern Africa. By PERCY ALBERT WAGNER. Published by the Transvaal Leader, Johannesburg, 1914.

An enlarged edition of the German volume which appeared in 1909. In three parts: 1, the primary occurrence; 2, the detrital diamondiferous deposits; 3, the diamond mining companies and statistics.

The volume is profusely illustrated and is an exhaustive treatise.

FUELS.

The Mode of Origin of Coal. By E. C. JEFFRY. Journal of Geology, May, 1915, p. 218.

Geology and Coal Resources of North Park, Colorado. By A. L. BEEKLY. U. S. Geol. Survey Bull. No. 596, 1915.

Investigation of the Peat Bogs and Peat Industry of Canada, 1911–12. Mines Branch, Department of Mines, Canada, Ottawa, 1914.

Contributions to Economic Geology, 1912, Part 2, Mineral Fuels. Short papers and preliminary reports, by various authors. U. S. Geol. Survey Bull. No. 541, 1914.

SALINES.

Salines in the Owens, Searles, and Panamint Basins, Southeast California. By HOYT S. GALE. U. S. Geol. Survey Bull. No. 580-L, 73 pp.

Reviews the general situation and mineralogy of the district.

CORUNDUM.

Corundum, its Occurrence, Distribution, Exploitation and Uses. By ALFRED ERNEST BARLOW. Memoir 57, Geological Survey of Canada, Ottawa, 1915.

A monographic account originally intended as part of the economic chapter in the Memoir on the Haliburton and Bancroft area, published in 1910.

LATERITE.

The Work of Lacroix on the Laterites of French Guinea. By L. L. FERMOR. Geol. Magazine, vol. 2, pp. 28–37, 1915.

An exposition dealing with the nomenclature, minerals of laterite, process and products of laterization, and the age of the laterites.

SCIENTIFIC NOTES AND NEWS[1]

PROFESSOR H. S. WILLIAMS, Emeritus Professor of Geology at Cornell University, has presented his personal library of about 3,000 volumes to the Department of Geology of Cornell University. It is to be known as the Williams Library of Geology.

THE U. S. GEOLOGICAL SURVEY has just published an interesting Bulletin (611), a Guidebook of the Western United States, which would prove an interesting companion for a trip over the Northern Pacific Route. As it is a government publication application should be made to the Superintendent of Documents Washington, D. C. enclosing $1.

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.